



PROJECT AIR FORCE

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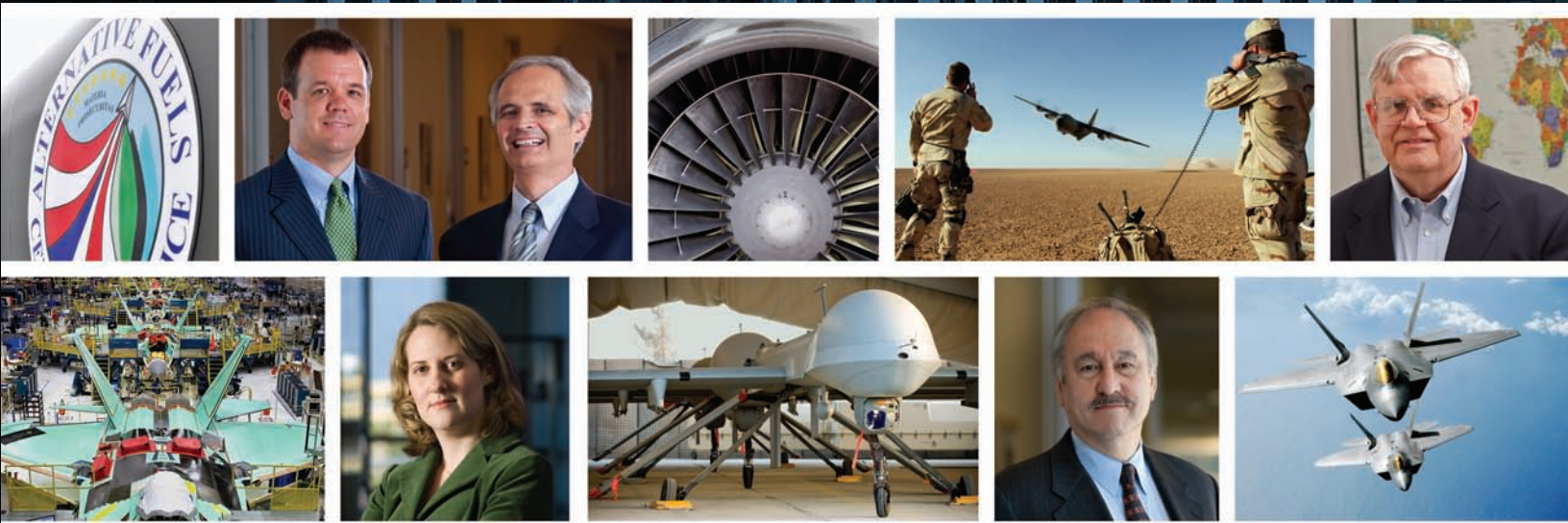
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Annual Report 2011



RAND

PROJECT AIR FORCE

Annual Report 2011



PROJECT AIR FORCE

About RAND Project AIR FORCE

The mission of RAND Project AIR FORCE (PAF), a division of the RAND Corporation and the Air Force's federally funded research and development center for studies and analyses, is to undertake an integrated program of objective, independent analysis on issues of enduring concern to Air Force leaders. PAF addresses far-reaching and interrelated questions: What will be the role of air, space, and cyber power in the future security environment? How should the force be modernized to meet changing operational demands? What should be the size and characteristics of the workforce? How can that workforce be most effectively recruited, trained, and retained? How should sustainment, acquisition, and infrastructure be streamlined to control costs? PAF carries out its research agenda in four programs that represent core competencies:

Strategy and Doctrine seeks to increase knowledge and understanding of geopolitical and other problems in the national security environment that affect Air Force operations. PAF maintains expertise in defense strategy; regional analysis; the objectives and tasks of evolving joint operations; and the potential contributions of air, space, and cyber power to joint operations, defense planning, and requirements for force development.

Force Modernization and Employment identifies and assesses ways in which technological advances and new operational concepts can improve the Air Force's ability to satisfy a range of future operational demands. This research involves assessments of technology feasibility, performance, cost, and risk. PAF assesses major force components needed in the future and the systems and infrastructure supporting their operations.

Manpower, Personnel, and Training concentrates on questions about workforce size and composition and about the best ways to recruit, train, develop, pay, promote, and retain personnel. PAF's research encompasses the total workforce: active-duty, guard, reserve, civilian, and contractor personnel.

Resource Management analyzes policies and practices in the areas of logistics and readiness; outsourcing, privatization, and contracting; the industrial base; planning, programming, and budgeting; infrastructure; and weapon-system cost estimating. The goal of this program is to maximize the efficiency and effectiveness of Air Force operations in a resource-constrained environment.

PAF also conducts research on topics that cut across all four programs, and its research staff regularly responds to Air Force requests for help on time-urgent problems.

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Message from the Director

In today's world, most of us are susceptible to the lure of novelty. We want the latest gadgets. We want faster and better ways to stay connected to family, friends, and colleagues. We want to incorporate technological advances into our daily lives. In short, we are fascinated by the prospect of *innovation*.

When I considered making innovation the theme of my message this year, I was aware that the term has become a buzzword, a staple of the marketer's lexicon. However, beyond its standard definition of something new or novel, I believe that innovation also represents a mindset that is expressed through ideas, methods, and basic approaches to problem solving. It is a hallmark of the Air Force and what the institution represents. Indeed, it was the airplane that helped a small group of modern military innovators understand that they could go over a problem rather than through it and thus helped break the stalemate that World War I had become. In a very real sense, the notion of "every airman an innovator" serves as the foundation of what the United States Air Force represents.

So, too, for RAND and especially for Project AIR FORCE.

I should make clear that the day-to-day work of RAND researchers seldom involves "eureka" moments. Rather, it requires diligent data gathering and meticulous analyses that gradually lead to sets of conclusions and recommendations for our Air Force sponsors. It



Andrew R. Hoehn

As PAF's director,
I am dedicated to creating
a research environment
that enables innovative
thinking. . . . ultimately
[coming] up with the
kinds of sound concepts
that reflect the strength
of combined intellect,
experience, and creativity.

involves developing new methodologies and applying them to novel problems. It sometimes involves hitting a dead end and starting all over again. But working hand in hand with our Air Force sponsors, who are integral to this process, we are able to tackle hard questions and produce new and sometimes unexpected results. Indeed, many times in PAF's 65 years of service to the Air Force, an individual or a team has stepped off the path and arrived at a solution to a complicated problem that could not have been foreseen when the study was initially undertaken.

Certainly, RAND's early work on deterrence theory and strategic basing would fit this category. But so, too, would our more recent work on new warfighting concepts in the western Pacific, the need for closer air and naval integration, the future of unmanned systems, the need for a global logistics and support system, the value of new types of precision munitions, and ways to increase the diversity of the force. Looking to the future, our ongoing work on how to fight in the presence of nuclear weapons without resorting to them or perhaps our efforts to redefine the needs of the combat air forces might also be judged as innovative.

As PAF's director, I am dedicated to creating a research environment that enables innovative thinking. This means encouraging our research staff to explore topics in what might seem to be unconventional ways. It means helping them find time to devote to such explorations—a particularly challenging task in an era when premiums are often placed on rapid responses to time-urgent issues. It means investing in new methods to complement old ones or, occasionally, to replace them. It means rewarding collaborative efforts that allow team members to brainstorm, challenge each other's ideas, propose alternatives, and ultimately come up with the kinds of sound concepts that reflect the strength of combined intellect, experience, and creativity.

The kind of innovation I am describing would not be possible without unwavering Air Force support. The RAND–Air Force partnership is built on decades of mutual trust and a mutual commitment to finding solutions to the nation’s hardest security problems. Again and again, the Air Force has demonstrated a willingness to reframe problems—How do we go over a problem rather than through it?—and consider options that may, on their surface, appear to be off the beaten track. Its forward-thinking, results-oriented approach has been, and will continue to be, a source of inspiration to Project AIR FORCE and a stimulus to innovation.

A handwritten signature in blue ink, reading "Andrew R. Hoehn". The signature is fluid and cursive, with the first name "Andrew" and last name "Hoehn" clearly legible.

Andrew R. Hoehn
Vice President, RAND Corporation
Director, Project AIR FORCE

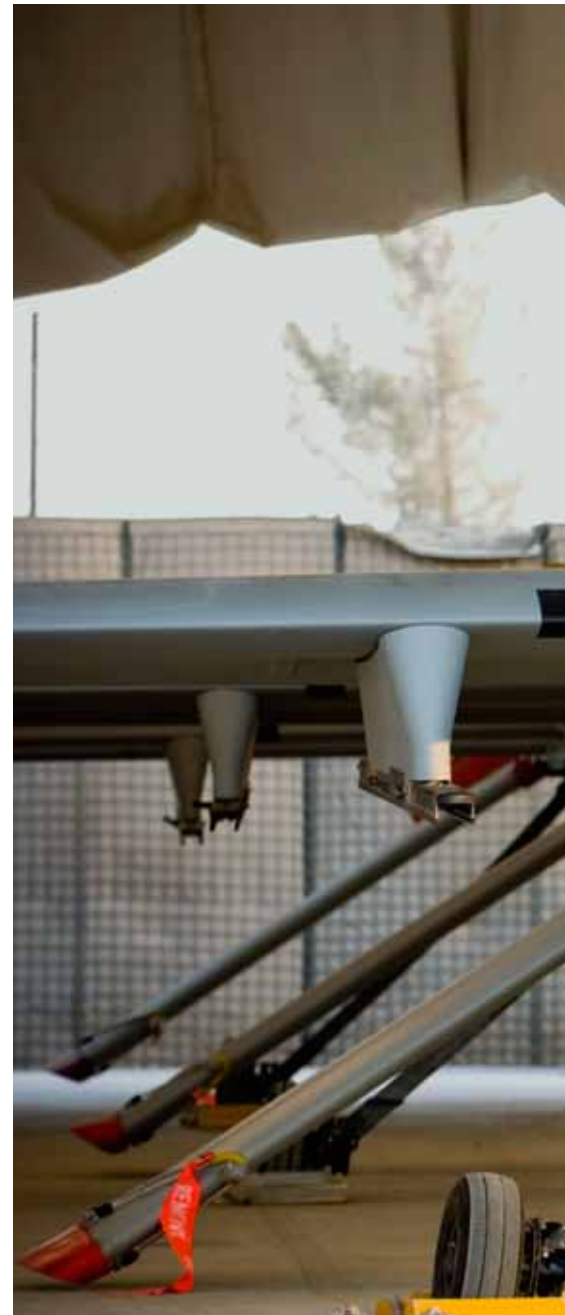
A Flood of Intelligence

How Can the Air Force Keep from Drowning in Data?

The development of advanced sensors and remotely piloted aircraft has enabled the Air Force to collect vital intelligence for joint and coalition warfighters in near real time. Advanced sensors include full motion video (FMV), signals intelligence suites, and moving target indicator radar. These collections have been at the heart of efforts to track down terrorists, to find improvised explosive devices, and to provide advance warning of danger to troops as they work among potentially hostile populations. But the flood of intelligence may be too much of a good thing unless the Air Force finds more efficient and effective ways to process, exploit, and disseminate the massive amount of data it collects.

FMV is a case in point. Medium-altitude aircraft equipped with certain sensors can provide warfighters with high-quality video feeds over an area of interest. This type of intelligence has been in such high demand that the Air Force has greatly increased the number of remotely piloted aircraft that provide FMV and is fielding wide-area airborne surveillance sensors that can provide many motion imagery feeds simultaneously from one aircraft. Imagery analysts working in the Air Force's Distributed Common Ground System (DCGS) are responsible for monitoring video feeds, identifying information of interest, transmitting intelligence to warfighters for immediate use, and archiving the data for later analysis. Current manning constructs require a dedicated crew of analysts for each FMV feed, with at least one of them monitoring the feed at all times. Thus, even while the Air Force endeavors to meet the demand for intelligence by providing more platforms and sensors, it risks creating an exponential increase in demand for imagery analysts in the DCGS.

In 2009, Lt Gen David Deptula, then Deputy Chief of Staff for Intelligence, Surveillance, and Reconnaissance (ISR), expressed concern that the Air Force may soon be "swimming in sensors and drowning in data." He asked RAND Project AIR FORCE (PAF) to help answer a crucial question: With respect to processing, exploitation, and dissemination (PED), should the Air Force seek to increase capacity or to find ways of working smarter? While there is no doubt that more PED manpower



Three MQ-1 Predators equipped with advanced sensors, including FMV, sit ready for launch in a hangar at a base in southern Afghanistan. The success of these platforms in recent operations has greatly increased the demand for FMV to support warfighters.



“Reality TV” production suggests a promising set of approaches. Although the subject matter is vastly different from that of military operations, and the stakes are not comparable, some technical and process challenges are surprisingly similar to those FMV analysts face.

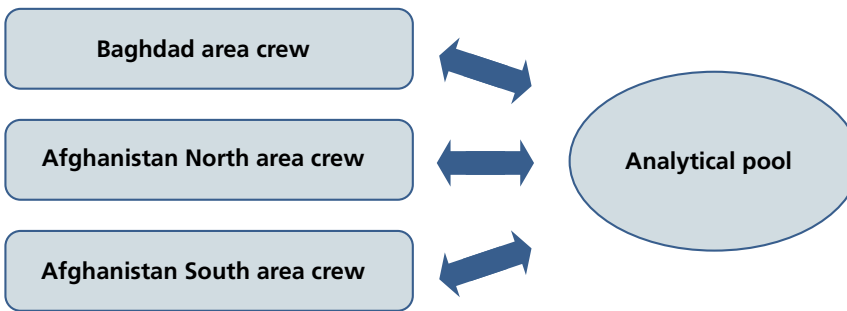
will be needed to meet future demand, lessons from the commercial world suggest that improved processes and tools can help the Air Force manage the problem and may even suggest ways to improve the kind of support it provides to warfighters.

Lessons from the Commercial World

Although the challenges of increasing motion imagery PED capacity and efficiency are relatively new for the Air Force, they are analogous to issues the commercial world has been dealing with for years. For example, “reality TV” production suggests a promising set of approaches. Although the subject matter is vastly different from that of military operations, and the stakes are not comparable, some technical and process challenges are surprisingly similar to those FMV analysts face in the DCGS. Indeed, it is possible to compare the typical staffing positions and duties of reality TV production crews to those of motion imagery PED crews, as shown in the table.

But there are important differences in how these crews are organized and how they use technology to increase their effectiveness. For example, in reality TV production, the control room is set up so that personnel sit facing a single bank of monitors capturing all feeds. Story editors follow specific actors across the feeds, thus gaining full insight into the “target” behavior, and the director is able to cross-cue multiple cameras to follow interesting action in real time. In contrast, each analyst in the DCGS is dedicated to a single feed and lacks good insight into the larger operating picture. Arena- and cluster-style seating, common at many (though not all) exploitation sites, further prevents analysts from seeing the broad operational context, which can help them interpret images more effectively. Opportunities to follow a target of interest across multiple feeds and even to correlate different kinds of intelligence (such as electronic signals and radar tracking) are not as apparent.

| Comparison of Air Force Motion Imagery PED and Reality TV Production Crews | | |
|---|---|---|
| Air Force Motion Imagery PED Crew | Reality TV Production Crew | Responsibilities |
| Mission operations commander (or ISR mission commander) | Show-runner (or executive producer) ^{a, b} | Manages entire operation |
| Imagery mission supervisor (or correlation analyst) ^c | Director | Oversees daily operations Watches for cross-cueing opportunities |
| Tactical communicator (or screener) | Assistant director | Acts as liaison |
| Imagery report editor Imagery analyst | Story producers and editors ^d Associate story producers | Generate products Keep their eyes on and log events |
| <p>^a <i>Show-runner</i> is an informal designation for the highest-ranking producer, who devotes his or her full attention to the show. Some producers work on more than one show.</p> <p>^b The management of a reality television show can be quite complex, with multiple executive producers in addition to the show-runner. The co-executive producers rank slightly lower but above any supervising producers. Supervising producers may, for instance, oversee shift work, much as the Air Force rotates through different mission operations commanders to support 24/7 operations.</p> <p>^c The correlation analyst's job is to coordinate cross-cueing opportunities with others, but if none arise, the individual can become more of a tactical communicator.</p> <p>^d These two positions differ largely in postproduction duties. Story producers create a script for each episode, while the editors string together the requisite footage.</p> | | |



Relationship Between
the Area Crews and
the Analytical Pool in
Area-Centric Operations

PAF recommended that the Air Force consider adopting a control room–style floor arrangement for motion imagery PED. It should also consider adopting the kinds of tools that help make reality TV production crews more efficient. These include gathering video and other relevant information (such as maps and radar intelligence) in one highly visible place to enable better insight into operational context and opportunities for cross-cueing. Speech-to-text commercial technology would also allow analysts to concentrate on video feeds while they are communicating with other analysts and warfighters.

Reorganizing for Area-Centric PED

Lessons from the commercial world suggest ways to make the existing FMV PED enterprise more effective, but fundamental changes in how PED crews are organized are also needed to enable the DCGS to meet the coming flood of data.

The current, platform-centric practice of assigning PED crews to individual collectors developed long before the advent of FMV, when ISR platforms were more scarce, imagery data were limited to still photographs, and collections were not expected to be exploited in real time. At present, most motion imagery is exploited as it arrives. As more sensors come online, the queue of unexploited data will grow exponentially until real-time support to warfighters becomes impossible.

To mitigate this situation, PAF proposed that the DCGS consider adopting an area-centric manning construct, illustrated in the figure. Under this construct, PED activities would be coordinated for an entire geographical area rather than for a single platform, and PED crew assignments would be based on the urgency and importance of the collections. Area crews, depicted on the left, would analyze imagery in real time (on the order of seconds or minutes) for the immediate use of warfighters in a given geographical area. The analytical pool, depicted on the right, would provide a surge capacity for area crews, performing less time-sensitive tasks in the meantime. A key point is that, while the overall number of people in the DCGS would remain constant, the size of the area crew would adapt to meet the demand represented by activity level and the number and types of collectors in the area. This construct would allow the DCGS to handle large amounts of data while meeting the needs of warfighters.

A second key point is that area-centric manning would coordinate all types of airborne intelligence collected in a given area, thus enabling the

Carl Rhodes and Amado Cordova

In the past two years, Carl Rhodes and Amado Cordova have often been asked, “What has reality TV got to do with the Air Force?” Carl, who co-led PAF’s ISR PED study with Amado, explains it this way: “Defense analysts—ourselves included—are used to thinking about ISR as largely a technological problem. That’s why most of the people who study it are engineers or physicists. But the value of ISR collection is drawn out by people, who use intuition, ingenuity, and common sense to understand what they are seeing. So we have to think about ISR PED as involving a set of human skills that are employed not only within the Air Force but also in the commercial world. In a sense, our research faces a similar challenge as Air Force PED personnel face: taking different kinds of knowledge from different sources and fusing it into something useful.”

Carl and Amado were chosen to lead PAF’s study of ISR PED capacity because of their talent for appreciating the operational and human implications of technological advances. Amado has a PhD in electrical engineering from Stanford University and holds 24 patents for innovations in fiber optics and navigation sensors. Carl has a PhD in chemical engineering from the California Institute of Technology and spent his early career developing theories and algorithms for modeling process control systems, which range from air conditioning thermostats to auto-landing capabilities on aircraft. Both came to RAND with the desire to apply their specialized scientific skills to broader policy questions.

“ISR research was a natural fit because of my background in sensor technology,” says Amado. “But I quickly realized that to understand the kinds of problems the Air Force was bringing to RAND, you also have to understand organizational psychology and manpower issues.” Amado engaged with RAND colleagues in these disciplines and applied his insights to the ISR PED realm. “It’s the kind of cross-disciplinary approach you only find at a place like RAND.” Amado also benefited from close interaction with Air Force operators. “I learned the most about Air Force PED by being on the floor of the DCGS with analysts at two o’clock in the morning. No matter how advanced the technology and the tools they use, it is their skills, training, and creativity that make possible their outstanding intelligence analysis results.”

Carl agrees. “Out of all the RAND projects I’ve worked on, this is the one where we had the closest involvement with the operational community. The operators were willing to experiment with our preliminary recommendations and to give us feedback. It broadened our understanding of what they actually face and how we can help them solve problems.”

As associate director of PAF from 2009 to 2011, Carl had the opportunity to further broaden his perspective across the full range of research areas including technology, manpower, resource management, and strategy. “The Air Force faces challenges that do not fit neatly into scientific disciplines,” he says. “Having a broader view is critical to solving even the most seemingly technical problems.”



Defense analysts—ourselves included—are used to thinking about ISR as largely a technological problem. That’s why most of the people who study it are engineers or physicists. But the value of ISR collection is drawn out by people, who use intuition, ingenuity, and common sense to understand what they are seeing. So we have to think about ISR PED as involving a set of human skills that are employed not only within the Air Force, but also in the commercial world.

kind of cross-cueing between sensors described above. For example, an area crew supervisor (whose job is analogous to that of the director in television production) would be able to identify hand-off opportunities between a moving target indicator radar, which detects movement in a restricted area, and an FMV sensor, which can be retasked to take a closer look or to provide overwatch for a ground patrol. In such a case, the area crew could monitor the situation, drawing from the analysis pool as needed and correlating different kinds of intelligence. Thus, an area-centric construct has the potential to reduce the number of people needed (compared to the platform-centric construct) and to enable PED crews to “work smarter.”

Developing Technology to Work Smarter

Certain technologies can greatly enhance the organizational area-centric construct. In addition to investing in improved video displays and exploiting commercial speech-to-text advances, as discussed above, PAF suggested that the Air Force monitor technology development in three areas:

- **Motion imagery processing and exploitation:** Tools are being developed that have a limited ability to automatically detect, identify, and track objects of interest. While they will not replace human observation, they may reduce the need to continuously monitor every video feed by allowing analysts to focus on potentially interesting events when they occur.
- **Motion imagery distribution and storage:** Many existing software tools make imagery available to users on request, but features differ widely between available tools. The Air Force should identify its own requirements for such systems as a first step toward evaluating and testing them.
- **Virtual collaboration:** Effective use of collaboration software can enable analysts at different DCGS sites to work together, provide surge capacity, and apply regional expertise where it is needed. The Air Force should encourage standardization of lexicons and other communications practices and provide training on the use of such tools to ensure that analysts can reap the greatest benefit from these capabilities.

Staying Ahead of the Problem

The Air Force has begun to experiment with tools and organizational constructs, such as alternative seating arrangements at exploitation sites, prioritization of FMV feeds that require real-time exploitation, use of video database software to facilitate storage and retrieval of intelligence, and use of headphones instead of text-based chat to make imagery analysts more efficient. Further experimentation will help the Air Force get ahead of the demand for intelligence and continue to provide this essential capability to joint warfighters.

Air Force Source Selections

A Few Sophisticated Bid Protests Are Posing Big Problems

A few years ago, the Government Accountability Office (GAO) sustained bid protests against the Combat Search and Rescue Recovery Vehicle (CSAR-X) and the KC-X aerial refueling tanker programs, making headlines and significantly disrupting Air Force resource and operational planning. Companies file protests with GAO's Office of General Counsel when they believe the military services or other government organizations have made an error during source selection that unjustly prejudices their chances of winning a contract. The protests against the CSAR-X program in fiscal year (FY) 2007 so disrupted Air Force planning that the resulting delays helped lead to the cancellation of the program. Meanwhile, the protests against the KC-X program in FY 2008 delayed this high-priority tanker recapitalization effort by three years, and the source was not selected until the beginning of 2011.

Air Force leadership has made a concerted effort to understand why GAO sustained these protests and how to avoid similar outcomes in the future. PAF undertook a broad analysis of the Air Force's performance during the bid protests. The researchers developed statistical models and conducted case studies to identify and understand trends in bid protests and made recommendations to help the Air Force focus its countermeasures where the threat of bid protests is the greatest.

Overall Air Force Performance in Bid Protests Has Been Positive

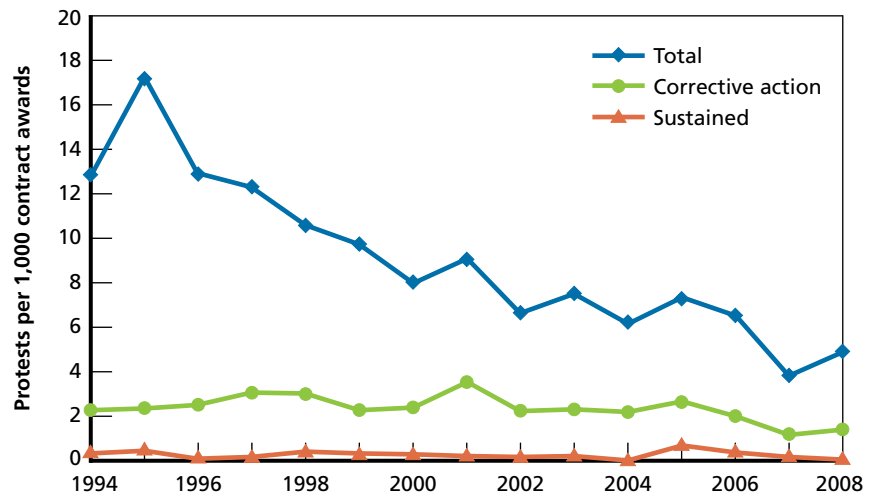
The PAF research team, led by Frank Camm, found that the Air Force's overall performance in GAO bid protests over the last two decades has been largely positive. As shown in the figure on page 12, the total number of Air Force protests as a share of total number of contract awards fell dramatically from FY 1994 through FY 2008. Indeed, it is so unusual for the GAO to sustain protests that they hardly register relative to the total number or the value of contract awards. On average, from FY 2000 through FY 2008, GAO sustained one protest for every \$20 billion the



In this artist's conception, a KC-46A (formerly the KC-X) prepares to refuel a B-1B bomber in flight. These next-generation aerial refueling tankers will replace the Air Force's KC-135 Stratotankers—the service's primary refueling aircraft for more than 50 years.



Trends in Air Force Bid Protests and Corrective Actions, 1994–2008



Air Force spent in acquisitions, and no trends were apparent in the ones the office did sustain.

When a protest occurs, the Air Force can voluntarily take corrective action to address the issues raised. For example, it can offer to reevaluate proposals, give companies an opportunity to adjust their proposals, or rewrite the request for proposal. GAO normally will dismiss a protest if such corrective actions satisfy the protest issues. The Air Force has taken such actions in noticeable numbers. The number of corrective changes per contract award (also shown in the figure) bobbed around until FY 2001, then began a long downward trend. Through the 1990s, the Air Force offered corrective actions in about 0.3 percent of contract awards. From 2001 to 2008, that number dropped to less than 0.2 percent of contract awards. This points to steady improvement over time.

The Air Force Needs to Concentrate on a Small Number of Sophisticated Protests

To analyze protest activity and outcomes more deeply, PAF researchers conducted case studies of the CSAR-X and KC-X source selections. Although these selections had some unusual characteristics (such as foreign companies competing for contracts), they shared two characteristics that the PAF team expects will occur repeatedly in a small number of future Air Force acquisitions. First, each acquisition had a high dollar value. The net revenue associated with large acquisitions is likely to encourage any loser in a source selection to launch an aggressive protest, even if the cost of that protest is substantial. Second, the winner of each competition was likely to emerge as the global front-runner for the capability in question, gaining an advantage not only in the U.S. market but in markets for other nations. Technology maturation and the learning curve that develops during the production process would give the winner an advantage in future competitions that any challenger would have difficulty overcoming. Taken to the extreme, failure in either source selection could have foreclosed a loser's future business opportunities. The stakes associated with each of these source selections were so high for the

loser that a costly campaign to protest the decision could be not only worthwhile but absolutely necessary to satisfy stockholders.

The main lesson the Air Force can learn from the pattern of protests is that it is likely to face such sophisticated protests again. Protesters appear to be learning how to achieve GAO sustainments, and their outside counsels are becoming increasingly capable of supporting or even designing such campaigns. One of the lessons protesters are learning is that it is hard for the Air Force to marshal sufficient resources to counter waves of sophisticated challenges, such as those launched against the CSAR-X and KC-X programs. In this arena, protesters have greater surge capacity than the Air Force does and may see a growing opportunity to stretch the Air Force's ability to respond.

Recommendations

The Air Force should be careful to protect the policies and practices that have, overall, supported a pattern of steadily improving performance. The threat manifested in the CSAR-X and KC-X programs appears to be relatively new. However, such protests will continue and could increase until the Air Force demonstrates that it can effectively counter them. The following are some of the steps PAF researchers recommended to reduce risks associated with sophisticated protests:

- **Recognize a bid protest as, in a legal sense, an adversarial proceeding with finely tuned rules and increase attention on how GAO views a bid protest.** GAO and the Air Force have separate and distinct missions that naturally come into conflict in bid protests. The better Air Force personnel understand how GAO views the protests, the more successful they will be in countering them.

The proposed CSAR-X, shown here in an artist's rendering, was intended to replace the Air Force's fleet of HH-60G Pave Hawk helicopters. However, bid protests first delayed the program and then helped lead to its cancellation.



- **Simplify and clarify selection criteria and priorities.** GAO's most common reason for sustaining a protest is a mismatch between the criteria stated in the request for proposal and how these criteria are used to evaluate proposals. The Air Force is already moving aggressively to ensure that the criteria and the evaluation process for a given selection match. The new approach for capability and requirements determination prescribed in the Weapon System Acquisition Reform Act could help clarify the relative importance of requirements in ways that promote this goal.
- **Tighten discipline throughout the source selection.** Small errors directly produced three of the ten grounds for protest in the CSAR-X and KC-X source selections. For example, the KC-X source selection generated hundreds of evaluation notices, which document how the Air Force evaluation team resolves various concerns about a contractor's proposal. The KC-X program office failed to track the status of one of these evaluation notices and, as a result, failed to see that the evaluation team had never explained how a particular concern was resolved. This failure led GAO to sustain the protest. Tracking tools are available to support greater discipline and simplify internal review of proposals. However, the KC-X and CSAR-X source selections did not have enough personnel with both the training and the experience in complex source selections to ensure careful documentation and control of the evaluation materials. More extensive coaching and training for such sophisticated protests would help personnel develop the skills they need to build quality into source selection and avoid sustained protests.

For More Information

Government Accountability Office Bid Protests in Air Force Source Selections: Evidence and Options, by Frank Camm, Mary E. Chenoweth, John C. Graser, Thomas Light, Mark A. Lorell, Rena Rudavsky, and Peter Anthony Lewis, DB-603-AF, forthcoming.

Analysis of Government Accountability Office Bid Protests in Air Force Source Selections over the Past Two Decades, by Thomas Light, Frank Camm, Mary E. Chenoweth, Peter Anthony Lewis, and Rena Rudavsky, TR-883-AF, forthcoming.

Government Accountability Office Bid Protests in Air Force Source Selections: Evidence and Options—Executive Summary, by Frank Camm, Mary E. Chenoweth, John C. Graser, Thomas Light, Mark A. Lorell, and Susan K. Woodward, MG-1077-AF, forthcoming.



Thomas Light

RAND associate economist Thomas Light was born and raised in Alamo, California, east of San Francisco. When it came time for college, he headed for the University of Oregon in Eugene to get his bachelor's degree in economics.

Tom went directly from undergrad to "cub economist." "Right out of college, I was lucky enough to get a great job in a consulting firm that an economics professor at the University of Oregon had started." Tom did economic analysis under the direction of people who had graduate degrees, and he benefited from their mentoring.

Four years later, he followed in his family's footsteps and went to Cornell, where his maternal grandfather, mother, and two of his dad's brothers had gone before him. There, he earned master's and doctoral degrees in economics.

Tom's dad was an antitrust lawyer. "His work on issues of industrial organization and competition for the California attorney general's office interested me. I began to see decisionmaking as an analysis of trade-offs, of costs versus benefits. The problem is," Tom continued, "this kind of thinking permeates not only my work life but my personal life as well. My wife, Leti, says it makes me very predictable. She always knows how I will approach a problem or frame an argument."

In 2007, Tom joined RAND, where his research focused on military acquisition and logistics, as well as on transportation, energy, and the environment. The Air Force acquisition work is stimulating, according to Tom, because "the Air Force and DoD are so large and so complicated. Not only is there a lot to learn, but there is a lot that can be improved. There is the potential for helping them save billions of dollars while preserving their ability to defend the United States and keep the military alive and vibrant."

Tom especially enjoyed the bid protest research because it brought together a diverse group of RAND colleagues. "We had a historian on the project who conducted interesting case studies on recent Air Force acquisitions that were protested successfully," said Tom. "His work, along with the contributions of others on the team, complemented the statistical analysis I conducted. In combination, we arrived at a robust set of findings and policy recommendations."

When he isn't modeling Air Force acquisition bid protests, tending to his one-year-old son, Will, or surfing in the Pacific across the street from RAND's Santa Monica headquarters, Tom teaches public finance in the Pardee RAND Graduate School (PRGS) and serves on dissertation committees for PRGS fellows. "I always talk up the graduate school because the students are really great. I love being part of the education process, and working with PRGS has been a real career highlight so far."

Tom is currently part of a research team that is investigating ways the Air Force can reduce fuel consumption. "The Air Force has the same concerns about fuel consumption as everybody else, only on a much larger scale. Fuel is expensive, and fuel costs are taking a bigger share of the Air Force budget."

Looking ahead, Tom hopes to continue to work on large, interdisciplinary projects. "I'll stay active in logistics and defense acquisition. There are loads of interesting and important problems to tackle in these areas. I like this work, and I want to become more of an expert."

We had a historian on the project who conducted interesting case studies on recent Air Force acquisitions that were protested successfully. His work, along with the contributions of others on the team, complemented the statistical analysis I conducted. In combination, we arrived at a robust set of findings and policy recommendations.

Shaking Up the Schoolhouse

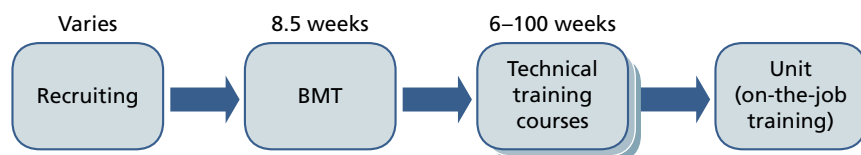
Reducing Washbacks and Attrition During Initial Skills Training

At the end of basic military training (BMT), recruits head to the “schoolhouse” for initial skills training in a career field generally chosen during the recruiting process. Schoolhouse training involves at least one technical training course but may also include multiple courses at different locations over an extended period. For example, recruits training for the pararescue career field take nine courses over 371 days at six training locations. Graduates of each career field program proceed to their first duty stations for on-the-job training as apprentices. Together with the recruitment phase, these stages make up the Air Force’s training pipeline (see the figure).

Washbacks (when recruits repeat a course) and attrition (when recruits leave training, voluntarily or otherwise) are costly. In fiscal years 2001–2008, Air Force washback and attrition rates for initial skills training averaged 21 percent and 8 percent, respectively. Attrition and washbacks can affect readiness by slowing the flow of personnel through the training pipeline. In recent years, they are estimated to have cost the Air Force \$112 million.

The Air Force asked PAF to examine the causes of attrition and washbacks during schoolhouse training for nine career fields that have had high rates of both. The table on page 18 shows attrition rates in a selection of courses for six of these career fields.

To begin identifying the contributors to training success and failure, the PAF team visited seven Air Force training sites. It interviewed 55 instructors and 154 students, held focus groups, administered a student questionnaire, and conducted quantitative analyses of data on personnel characteristics and training outcomes. Finally, the team reviewed screen-



After establishing a runway and clearing airspace, combat controllers give a C-130 takeoff clearance and provide air traffic control during a mission at an undisclosed location in support of Operation Enduring Freedom. The combat controller specialty was one of the nine career fields PAF examined.



Most of the eliminations from the pararescue specialty occur in the very first course in the pipeline, Pararescue Indoctrination, which is physically intensive and psychologically stressing and designed to push trainees to the edge of their physical abilities.

| FY 2008 Attrition Rates for Selected Courses in Six Air Force Career Fields | | |
|---|----------------------------|----------|
| Air Force Specialty | Course | Rate (%) |
| Air Traffic Control | Radar Apprentice | 23.2 |
| | Tower Apprentice | 21.7 |
| Combat Control | Operator Fundamentals | 33.3 |
| | Operator Tower | 29.2 |
| | Apprentice | 35.5 |
| | Orientation | 43.6 |
| Explosive Ordnance Disposal | Apprentice | 35.6 |
| | Preliminary | 29.2 |
| Pararescue | Indoctrination | 60.9 |
| | Aerospace Ground Equipment | 5.8 |
| | Air Force Combat Dive | 36.4 |
| Intelligence | Operations Apprentice | 21.4 |
| | Network Apprentice | 12.5 |
| Linguist | Far East Crypto Logic | 31.0 |
| | Pashtu Basic | 49.4 |

ing tools, Air Force physical fitness studies, research on recruiting, and proposed and ongoing Air Force initiatives to reduce attrition.

Some Contributing Factors Were Unique to Individual Career Fields

Every career field the PAF team investigated, even fairly similar ones, had unique training issues. The following subsections highlight findings and recommendations for two of these fields.

Pararescue

Pararescue comes under the general heading of special forces, although the Air Force prefers the term *battlefield airmen*. Pararescue personnel search for and rescue downed aircrews, recover materiel, and provide emergency trauma and field medical care. They are trained to function in friendly, denied, hostile, or sensitive areas and in a range of geographic environments, from arctic and urban to mountains, deserts, jungles, and water. The average cost per graduate, from recruitment through school-house training, is \$250,000.

Over 61 percent of recruits to this specialty are eliminated during initial skills training. Most of the eliminations occur in the very first course in the pipeline, Pararescue Indoctrination, which is physically intensive and psychologically stressing and designed to push trainees to the edge of their physical abilities. The two most common reasons the

PAF team found for attrition from this course were extreme aversion to water drills (24 percent) and physical deficiencies (22 percent). Many pararescue trainees felt that the physical fitness demands of BMT had not been sufficiently challenging for candidate battlefield airmen. Consequently, their physical fitness decreased during BMT to the extent that they failed to meet the specialty's fitness requirements during initial skills training.

At the time of the study, the Air Force had just instituted the concept of *Fit Flights* for certain career fields with exceptional physical demands (e.g., battlefield airmen). Members of Fit Flights are currently interspersed among regular trainees within a few squadrons and do not engage in additional physical exercise. The PAF team recommends that Fit Flights include only battlefield airmen, which would allow them to engage in separate, more demanding physical training.

Explosive Ordinance Disposal

Explosive ordinance disposal (EOD) requires the ability to locate, identify, disarm, neutralize, recover, and dispose of hazardous explosives; conventional, chemical, biological, incendiary, and nuclear ordinance; and criminal and terrorist devices. EOD training consists of three courses and takes 151 days. At Eglin Air Force Base (AFB), the U.S. Navy runs the primary training program for all the services. The average cost per graduate is \$63,000.

For the main EOD training course at Eglin AFB, attrition averaged 33 percent from 2001 to 2008. The primary reason was academic deficiency (77 percent); the second was voluntary disenrollment (14 percent). The Air Force had the highest attrition rate of all four services at the joint

Senior Airman Jeremy Garrett lowers a Stokes rescue basket down into the waiting hands of pararescuemen during the Keen Sword exercise at Kadena Air Base, Japan, in December 2010.



Although many reasons for washbacks and attrition were specific to individual career fields, some applied to the majority of the specialties examined.

school. This appeared to relate directly to the proportion of trainees without previous service experience: Over three-quarters of Air Force trainees are just beginning their careers, while the sister services are more likely to send midcareer personnel. Increasing the ratio of prior-service students should lower the overall attrition rate.

The Air Force also has the shortest preparation program for EOD training. While the Army and Navy each offer a ten-week preparation course, the Air Force offers only a six-day course. Longer preliminary training could reduce attrition, but increasing the proportion of prior-service students would be even more effective. Finally, as previous research suggests, another way to reduce attrition would be to use non-cognitive screening tools to evaluate the maturity and confidence of potential trainees, as well as other indicators of their potential to succeed in EOD.

Some Contributing Factors Apply to Most Career Fields

Although many reasons for washbacks and attrition were specific to individual career fields, some applied to the majority of the specialties examined. The PAF analysis identified three overarching sources of washbacks and attrition: recruitment practices, the Air Force's phase program, and incompatibilities between the training day and base operating hours.

Recruiting

Since these are demanding career fields, it is important that recruits understand what they are getting themselves into. A poor match between recruit and career field increases the likelihood that the recruit will fail to complete his or her training program.



A U.S. Air Force EOD specialist working out of Forward Operating Base Mehtarlam in Afghanistan's Laghman Province prepares for a controlled detonation in September 2007.

About 20 percent of all recruits interviewed said that they were not given enough information about a career field to really understand whether it would be a good fit. For example, operations intelligence trainees repeatedly commented on the disparity between how the career field was described to them and the reality of the job. Several trainees and even a few instructors recalled reading or being told that operations intelligence was “like being James Bond.” Such unrealistic expectations can contribute to both involuntary and voluntary attrition.

About one-third of pararescue, combat control, and EOD trainees claimed that their recruiters knew little about these career fields. Over one-half claimed to have obtained information on their own initiative from such sources as friends and the Internet. Some also said that they were not given enough information about other potential jobs for which they might have been better suited. A few said that they were given incorrect information about whether they could switch to other career fields or could separate from the Air Force if they did not like the job or if they failed training.

On the other hand, there were reports of exemplary recruiter assistance. Trainees described recruiters who made an extra effort to properly educate them about career fields they were considering. They especially valued the opportunities that recruiters provided for meeting someone in career fields of interest to the trainee.

The PAF team recommended that career field managers provide more information to recruiters about career fields, the training involved, and how to prepare for it. Recruiters could also engage the services of nonrecruiters from a range of career fields to share useful information with trainees.

The Phase Program

The phase program is designed to take recruits gradually from the very controlled environment they experienced during basic military training to a less strict environment by increasing their privileges in gradual steps. At the time of the PAF study, trainees generally spent 14 days in Phase I, 21 days in Phase II, and 150 days in Phase III. Trainees remain in the program for the length of their training, but may qualify for graduation from it after six months.

Trainees with fewer than four weeks of technical training were positive or at least neutral about the program, but more than three-quarters of those with four to six weeks of training were overwhelmingly negative. They reported that rules were inconsistently applied, dorm life was stressful and lowered morale, and study time was inadequate. Many were concerned about the potential of being sent back to Phase I or II for minor infractions. In addition, they considered the phase program unfair because trainees with shorter training programs moved to their first duty stations and a more lenient disciplinary environment earlier than trainees in longer training programs.

The PAF team concluded that the phase program is good overall and should not be discontinued. However, after considering feedback from trainees and staff and the amount of time trainees spent in Phase III, the

Tom Manacapilli

Tom Manacapilli's career in operations research began on his family's farm near Chippewa Lake in Ohio. "As a kid, I was fascinated by the wargames in *Strategy and Tactics* magazine, which I had come across in a chess publication," he recalls. Living on a 40-acre farm, he didn't have much time for them, so he would carve out a half hour by feeding the livestock as fast as he could, and then sit in the barn reading the rules for that month's wargame. "I was afraid that if I went into the house, I'd be given another chore."

At the time, operations research was not on his radar, and neither was an Air Force career or, for that matter, college. "No one in my family had attended college, and I hadn't thought of going either, but my chess club advisor pushed me to take an entrance exam. I did pretty well, especially in math and science." The eldest of seven children, he financed his education at Bowling Green State University by joining ROTC, winning an Air Force scholarship and working summers in a sheet metal factory. He earned a BS in mathematics from Bowling Green and an MS in operations research from the Air Force Institute of Technology.

Tom's first duty station was Langley AFB in Virginia, the headquarters of Tactical Air Command (TAC). "I joined the Air Force to finance my education, but I fell in love with it at TAC," he says. "TAC headquarters had very few personal computers in 1982," he explains. "My supervisor asked me to build a program to track aircraft, something that was done by pencil and paper at the time." His work attracted the attention of then Brig Gen Merrill McPeak (who was later to become Air Force Chief of Staff). "He started asking me up to his office to discuss changes to the program." Tom ended up developing the first-ever computer model for programming aircraft into squadrons and wings.

He was hooked, and he stayed in the Air Force for 20 years, five of them at the Pentagon, first as an analyst with the Air Force Studies and Analysis Agency, then with the Air Force Directorate of Air and Space Operations, and finally with the Special Assistant to the Vice Chief of Staff for Long-Range Planning. A few years later, when he was finishing up a tour as commander of the Air Education and Training Command Studies and Analysis Squadron at Randolph AFB, he decided to investigate opportunities at RAND. "In my mind," he says, "it was a dream job."

He joined RAND in 2000, applying his expertise in operations research, modeling and simulation, and defense planning to a series of projects related to post-secondary education and training. In 2004, RAND honored Tom with a Bronze Award for his work on cost and capacity modeling of the technical training pipeline for the Air Education and Training Command.

Tom still likes to play wargames and still finds it difficult to carve out time to play them. In addition to frequent travel for RAND, he and his wife, Sharon, are active in a faith-based nonprofit organization that ministers to college students and military personnel. "I really enjoy working with young people who are near college age. If someone hadn't pushed me toward college or bettering myself, I might have missed out on some wonderful opportunities and experiences. I want to help young adults achieve their dreams."



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team suggested splitting Phase III into two parts. Once trainees entered the second half, they could not be sent back except for egregious offenses. An alternative would be to end the program after six to eight weeks for all career fields.

The Training Day and Base Operating Hours

At all but one of the training bases the team visited, many service and support facilities closed before the end of the eight-hour training day. In many cases, this contributed to washbacks and possibly attrition. Even simple tasks, such as going to the post office to send packages during the lunch hour, can be complicated because so many other trainees are trying to do the same thing.

PAF recommended that training bases consider adjusting the work schedule of clinics, administrative services, postal services, and clothing alterations to better accommodate the needs of trainees. Another option the research team proposed was to reduce the training day to six hours, which would give trainees time to run errands and make clinic appointments without missing instruction. A number of the instructors interviewed suggested that information covered in eight hours could just as easily be taught in six. Another benefit could be improved information retention. Some squadrons use the extra two hours for hands-on training and simulation activity to reinforce what was taught during the first part of the day. The extra two hours would also provide the trainees some downtime, a need voiced repeatedly in the student interviews.

The Air Force Is Revamping Schoolhouse Training

The Air Force is now in the process of implementing several of PAF's recommendations to improve initial skills training in individual career fields and is considering other improvements. Such changes as adopting noncognitive screening tools, grouping battlefield airmen candidates together in BMT to ensure a higher level of physical fitness, and assigning special forces personnel as recruiters have the potential to save \$7 million per year.

The Air Education and Training Command is also examining options to include more prior-service trainees in EOD. The command has also implemented or is in the process of implementing several recommendations that apply to all career fields, such as modifying the phase program so that the duration of restrictions is the same for all recruits; evaluating options at training bases to schedule service and support facility operating hours around trainees' schedules; and improving the information available to recruits about career fields.

These efforts attest to the U.S. Air Force's commitment to continuous investment in and improvement of its training programs, one reason that it remains the finest trained air force in the world.

For More Information

Reducing Attrition in Selected Air Force Training Pipelines, by Thomas Manacapilli, Carl F. Matthies, Louis W. Miller, Paul Howe, P. J. Perez, Chaitra M. Hardison, Hugh G. Massey, Jerald Greenberg, Christopher Beighley, and Carra S. Sims, TR-955-AF, forthcoming.

Flying Jet Aircraft on Coal or Vegetable Oil

The Potential of Alternative Fuels for Military Applications

To reduce its reliance on petroleum-derived fuels, the Department of Defense (DoD) has spent hundreds of millions of dollars over the past few years to develop, test, and certify alternative fuels—that is, liquid fuels manufactured from renewable sources of energy (such as animal fat, vegetable oil from seeds or algae, and various types of biomass) or from nonpetroleum fossil fuels (such as coal or natural gas). The Air Force has played a leading role in DoD efforts to evaluate and test alternative fuels for military applications.

A continuing line of research at RAND has helped inform these efforts and contributed to the debate on energy policy issues. In it, RAND has striven to balance the needs for energy security, environmental protection, and financial cost. It has done so by maintaining expertise in a range of disciplines, from chemistry and environmental science to engineering, economics, and international relations. As this highlight will show, researchers with expertise in these disciplines move across RAND divisions as needed, conducting research for diverse sponsors and in conjunction with other organizations. These complementary efforts add up to a wealth of experience that the Air Force can readily draw on to make critical policy, management, and technical decisions affecting research and development on alternative fuels for military use.

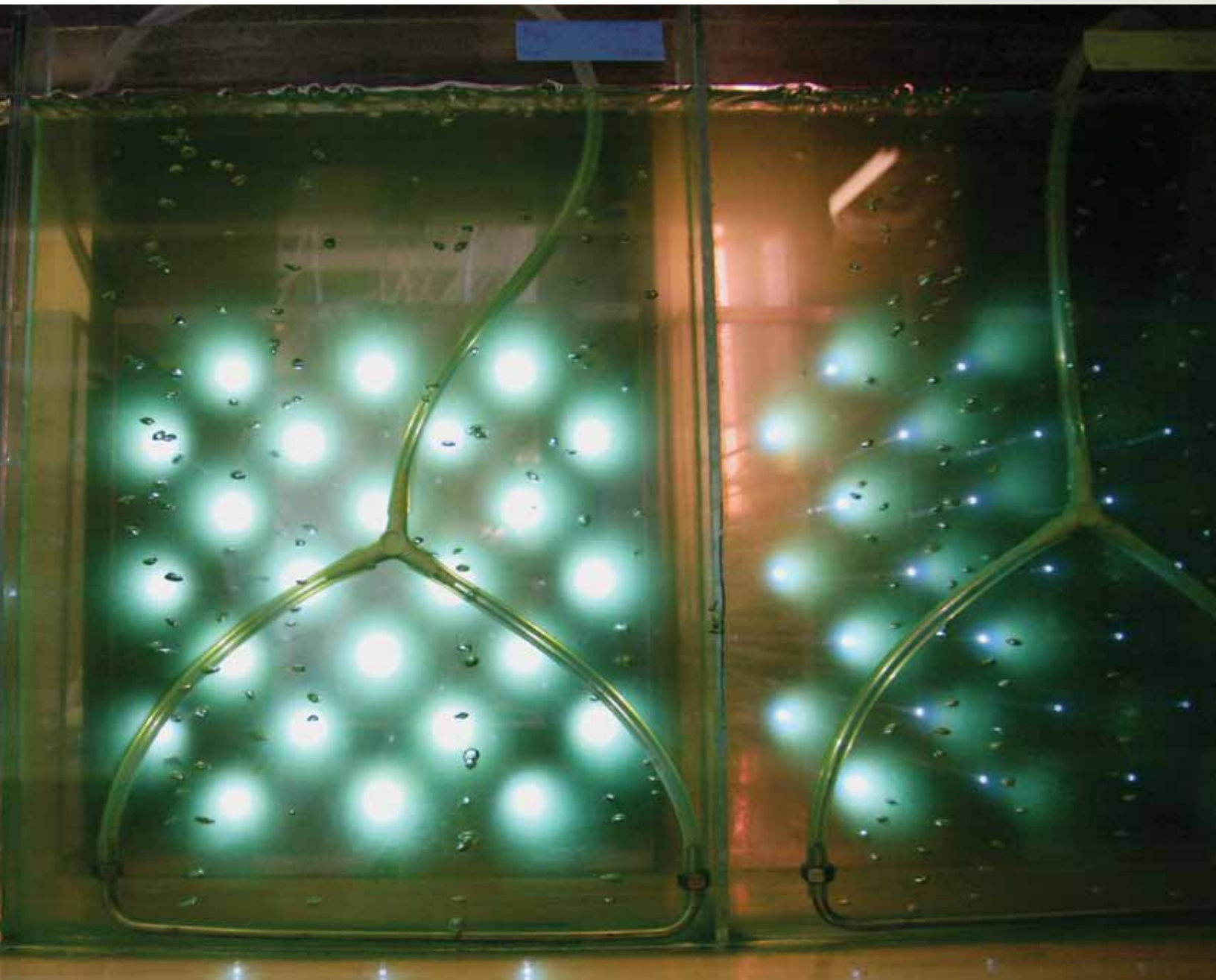
Described below are some of the key findings from two RAND reports that assessed the economic viability and technical readiness of alternative fuels. Both analyses were led by James (Jim) T. Bartis, a senior policy researcher at RAND, but were conducted under the auspices of three RAND divisions, including PAF.

Producing Liquid Fuels from Coal Is Potentially Viable in the Near Term If Greenhouse Gas Emissions Are Managed

During 2007 and 2008, world petroleum prices rose sharply, renewing interest in producing liquid fuels from coal. At the request of the U.S. Air Force and the U.S. Department of Energy, PAF joined with RAND Infra-



Sunlight from a solar collector on the roof of Utah State University's Energy Laboratory in Logan, Utah, is sent through fiber optics to stimulate the growth of algae. The university was among several institutions to receive DoD grant money in 2009 to research ways to convert algae into biofuels for military jets.



The necessary technology already exists. Commercial [coal-to-liquid fuel] production has been under way in South Africa since the 1950s using a process that begins with coal gasification and centers on the Fischer-Tropsch fuel production method.

structure, Safety, and Environment to investigate the costs and benefits of developing a coal-derived liquid fuel industry within the United States. The authors of the subsequent report concluded that large-scale production of liquid fuels from coal in the United States is technically feasible and potentially viable commercially, although important uncertainties remain.

The analysis showed that dedicating only 15 percent of the recoverable coal reserves of the United States to coal-to-liquid production would yield roughly 100 billion barrels of liquid transportation fuels, enough to sustain 3 million barrels per day of production for more than 90 years. Moreover, the necessary technology already exists. Commercial production has been under way in South Africa since the 1950s using a process that begins with coal gasification and centers on the Fischer-Tropsch fuel production method. The Fischer-Tropsch method has been recently updated through the construction and startup of two large commercial production facilities in Qatar. These facilities convert natural gas to exceptionally high-quality diesel and jet fuels.

Despite its promise, private investment in coal-to-liquid production has been impeded by uncertainties about the actual costs of producing coal-derived fuels and how to regulate greenhouse-gas emissions. The issue of managing greenhouse emissions is especially important. Without efforts to manage emissions, producing and using coal-derived liquids could roughly double the rate at which carbon dioxide (CO₂) is released into the atmosphere. Capturing the CO₂ from a coal-to-liquid plant is straightforward and much less expensive than removing it from the flue gas of a coal-fired electric power plant. For coal-to-liquid plants near oil fields, the carbon thus captured could be stored underground after being used to enhance petroleum recovery, yielding two barrels of conventional petroleum and one barrel of coal-to-liquid fuel at overall greenhouse gas–emission levels comparable to those for conventional petroleum production and use.

It is also possible to produce alternative liquid fuels from coal at overall greenhouse gas–emission levels that are much lower than those from conventional petroleum. For this to occur, the coal-to-liquid plant needs to be configured to accept a combination of coal and biomass and to capture and sequester nearly all the CO₂ generated at the plant site.

Thus, within a few years, coal-to-liquid plants could begin to alleviate the growing global dependence on price-controlled conventional petroleum without increasing greenhouse gas emissions over those of conventional petroleum products. Weighing these benefits and costs, including environmental costs, the authors concluded that it would make sense for the United States to promote a limited amount of early commercial experience in coal-to-liquid production that includes management of associated greenhouse gas emissions.

Hydrotreated Renewable Oils Are Not a Credible, Climate-Friendly Option Within the Next Decade

After the coal-to-liquid fuels research was completed, Jim led a related analysis mandated by Congress in the National Defense Authorization Act for Fiscal Year 2009. The Defense Logistics Agency selected RAND's

National Defense Research Institute to conduct the analysis, which assessed a range of alternative fuels that might be candidates for military applications over the next ten years, including fuels derived from renewable oils.

Alternative military fuels derived from renewable oils are produced by processing animal fats or vegetable oils (from seed-bearing plants, such as soybeans, jatropha, and camelina) with hydrogen. Various types of algae also have high oil content and are another possible source of oil for hydrotreatment. Fifty-fifty blends of hydrotreated oils have been successfully demonstrated in flight tests sponsored by the commercial aviation industry, and laboratory analyses and testing strongly suggest that hydrotreated renewable oils can also be formulated for use in tactical weapon systems. Unfortunately, it is highly unlikely that appreciable amounts of these renewable oils can be affordably and cleanly produced in the near future.

Animal fats and waste vegetable oils may offer an affordable low-greenhouse-gas route to hydrotreated renewable oils, but current supplies are already used for other commercial purposes. Because the supply of these materials is limited, substitutes would need to be found for other applications, and the substitutes might increase greenhouse gas emissions. Production potential is also an issue with animal fats and waste oils: The available supply of these materials will likely limit production to no more than 30,000 barrels per day, which is less than 0.2 percent of the 18 million barrels of liquid fuels that are consumed each day in the United States.

To keep life-cycle levels of greenhouse gas emissions for fuels derived from vegetable oils lower than those for petroleum-derived fuels, these oils must come from crops that do not compete with food production and that minimize adverse direct and indirect changes in land use. Jatropha and camelina are often mentioned as ideal plants to meet these

An airman prepares to fuel an A-10 Thunderbolt II on March 25, 2010, with a 50/50 blend of hydrotreated renewable jet fuel and JP-8 at Eglin AFB, Florida. The A-10 then flew what was the first flight of an aircraft powered solely by a biomass-derived jet fuel blend.



requirements, but little evidence currently exists to back these claims. Even if low-greenhouse-gas approaches can be established and verified, total fuel production is likely to be very limited. Producing just 200,000 barrels per day (about 1 percent of U.S. petroleum consumption) from these crops would require an area equal to about 10 percent of the croplands currently under cultivation in the United States.

Advanced approaches using algae or other microorganisms may offer a sustainable approach for producing hydrotreated renewable oils suitable for military applications. However, technological development challenges suggest that it is highly unlikely that these advanced approaches will constitute an important fraction of the commercial fuel market until well beyond the next decade.

Overall, the authors concluded that DoD investments in large-scale testing and certification of hydrotreated renewable oils are premature and should be discontinued. This recommendation was based on the highly limited production potential of seed oil and the major technical uncertainties associated with sustainable oil production from algae.

DoD Investment in Alternative Fuels Will Benefit the Nation as a Whole More Than It Does the Defense Community

Both reports concluded that the primary potential benefits of DoD efforts to develop alternative fuels will accrue more to the nation as a whole than to the defense community. Although the alternative fuels examined in these reports could technically meet military needs, they offer no particular military benefit over their petroleum-derived counterparts. For example, even if they can be produced at costs below the prevailing prices of conventional fuels, alternative fuels will be priced at market rates, so using such fuels will not lower DoD's costs. The authors also examined concepts for forward-based production of alternative liquid fuels. Because alternative fuels would need to be shipped to forward-based units in much the same manner as conventional fuels, they would not appreciably reduce the logistical burden of delivering military fuels.

Despite the absence of a compelling military benefit, alternative fuels may offer nationally important benefits. If DoD were to encourage early production experience, government decisionmakers, technology developers, and investors might obtain important information about the technical, financial, and environmental performance of various alternative fuel options. If favorable, that information could lead to a commercial alternative-fuel industry producing strategically significant amounts of fuel in the United States.

The finding that alternative fuels offer the armed services no direct tactical or operational military benefit is consistent with findings of other recent studies on military energy issues: Namely, that the military is best served by ongoing efforts to use energy more efficiently. This suggests that DoD and Congress should decide whether to continue to support the development of advanced technology for producing alternative liquid fuels through defense appropriations or to focus such efforts within the Department of Energy.

For More Information

Producing Liquid Fuels from Coal: Prospects and Policy Issues, by James T. Bartis, Frank Camm, and David S. Ortiz, MG-754-AF/NETL, <http://www.rand.org/pubs/monographs/MG754.html>

Alternative Fuels for Military Applications, by James T. Bartis and Lawrence Van Bibber, MG-969-OSD, <http://www.rand.org/pubs/monographs/MG969.html>



James T. Bartis

Findings from *Alternative Fuels for Military Applications* stirred considerable controversy, bringing lead author James T. Bartis to congressional hearing rooms three times to testify before the Senate and House energy committees. They also led to interviews on CNN, CNBC, Fox News, National Public Radio, and the Voice of America and were featured in articles by the *New York Times*, *Wall Street Journal*, *Air Force Times*, *Time Magazine*, and the *Huffington Post*, among many other media outlets. “When we started this study,” Jim explains, “many people did not know how little military benefit there was in alternative fuels. If you are concerned about defense and energy, what is on the critical path right now is more efficient use of energy. Energy-efficient aircraft, ships, and buildings—that is where we need to push the envelope, not alternative fuels.”

Jim is a senior policy researcher at RAND with over 30 years of experience in analyzing and assessing energy technology and policy issues. But public policy was the last thing on his mind while a student at Brown University, where he earned a BS in chemistry, and at the Massachusetts Institute of Technology, where he received a PhD in chemical physics. “The idea of public service gradually became important to me as I watched our government manage the Vietnam War era,” he says. Jim left the chemistry department at Cornell University for Washington, D.C., to join the Institute for Defense Analyses and, a few years later, the newly established Department of Energy, where he got to know RAND through several studies that he sponsored.

His first major assignment at the Department of Energy focused on the viability of coal-derived liquid fuels. “In 1978, there was a lot of money about to be spent on large-scale demonstrations of certain coal-to-liquid technologies. Fortunately, that didn’t happen. Advocates were claiming that the technology was just around the corner in terms of commercial viability, but they were proven to be overly optimistic.” Almost 30 years later, he had an opportunity to revisit alternative fuel issues at RAND, where he published *Oil Shale Development in the United States: Prospects and Policy Issues*, which became the most-downloaded report on RAND’s website in fiscal year 2006 and continues to draw attention on Capitol Hill today.

Jim received RAND’s President’s Choice Award in 2007 for helping RAND earn a secure place in the energy policy debate. However, when he joined RAND in 1998, Jim welcomed the opportunity to conduct research on new topics. In 2001, he was starting a study on the protective equipment needs of emergency responders for the National Institute for Occupational Safety and Health. “We were just setting up initial meetings when the September 11 attacks happened,” he recalls. “The study was completely redirected to address 9/11. We produced a four-volume series of reports, and some of our key findings were incorporated in the Department of Homeland Security’s plans for emergency preparedness and response.”

For Jim, the highlight of 2011 has roots in much less dramatic experiences that reach back to his years in academe and reflect his love of science. “My youngest son, who is a graduate student in materials science, came across a review that described a 1974 paper on chemical reaction theory that I had coauthored as ‘seminal.’ I had no idea I had written a seminal research paper,” he laughs. “But I made sure that a few of my fellow physical scientists at RAND heard about it.”

When we started this study, many people did not know how little military benefit there was in alternative fuels. If you are concerned about defense and energy, what is on the critical path right now is more efficient use of energy. Energy-efficient aircraft, ships, and buildings—that is where we need to push the envelope, not alternative fuels.

Nuclear Deterrence Revisited

What Does Russia's Emerging Deterrent Framework Mean for the U.S. Air Force?

The Cold War is over, but its legacy lingers. As the United States and Russia continue to define and shape their relationship, one of the positive developments is that neither side currently sees itself as perpetually under threat of nuclear attack from the other. Both nations are thus prepared to draw down the strategic nuclear forces that defined the central hostility of the Cold War. However, even though constant vigilance is no longer required, real, if nonviolent, conflicts of interest remain, including Russia's efforts to recover from a period of weakness and reassert itself as a great power.

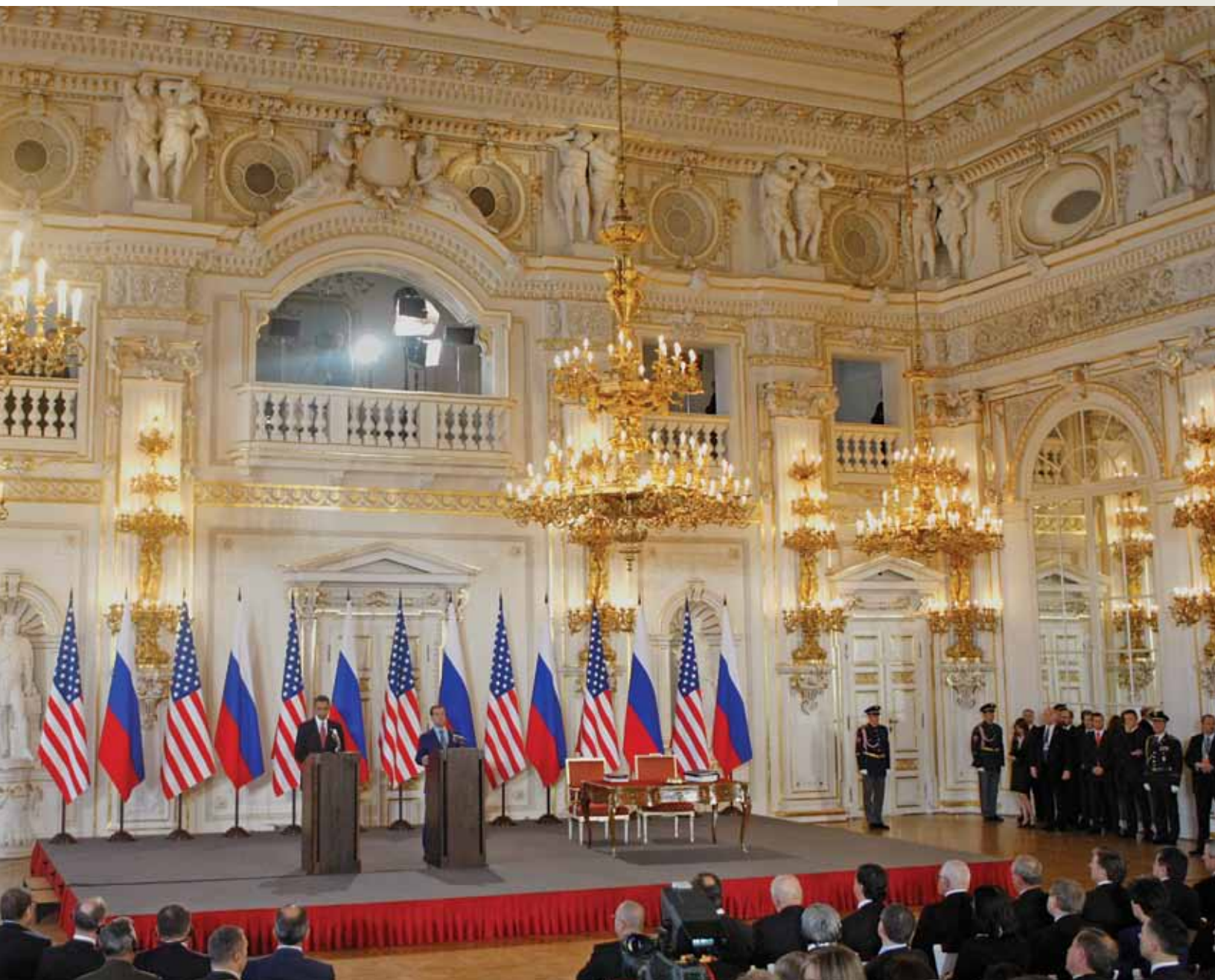
The Air Force has always had a special role in understanding the possible use of nuclear weapons in any conflict. A recent PAF study looks at whether and how Russia might come to use such weapons if a conflict in or near Europe were to escalate. The elements of such scenarios are unlikely to resemble those of the past, which means that new deterrent mechanisms will be needed.

The Cold War Deterrent Framework Was Designed to Protect the Vital Interests of Both the Soviet Union and the United States

The purpose of deterrence during the Cold War was to protect the vital, clearly stated interests of both the Soviet Union and the United States. To accommodate these interests, each side extended its deterrence in various ways to encompass its allies (NATO for the United States and the Warsaw Pact for the Soviet Union, for example). The framework that emerged involved the deployment of large numbers of conventional and nuclear weapons. Their deterrence value further benefitted from demonstrations of intent through published military doctrine and weapon system exercises. Both sides made it clear that they were serious about and capable of defending their interests.



U.S. President Barack Obama, left, and his Russian counterpart Dmitry Medvedev, right, attend a press conference after signing the "New START" treaty in Prague, Czech Republic, on April 8, 2010. The treaty reduces the number of long-range nuclear weapons maintained by the two countries.



For both the East and the West, large annual field exercises involving hundreds of thousands of service members and thousands of aircraft and vehicles could and did serve both as rehearsals and as political statements.

Moreover, each system claimed authority over matters in its sphere of interest. The most marked and long-lasting demonstration of this authority was a physical boundary: the inter-German border.

Each side was willing and able to defend its claims with force, including nuclear weapons. That the end state of any such conflict would have been unsatisfactory, regardless of how it began, was the central theme of Cold War deterrence.

Soviet Cold War Deterrence Rested on a Multipart Framework

Looking back, the Soviet Cold War deterrent framework comprised four elements:

- **Authoritative Statement of Claimed Interests.** The most important element was the Soviet Union's statement of the interests it claimed and its intention to deter infringement on them. Deployment of Soviet forces supported this statement.
- **Military Doctrine and Practice.** Formal doctrinal publications offered the official positions on these matters, which were in turn reflected in research journals. Whether or not an individual was known to subscribe to these positions affected selection, promotion, and demotion decisions.
- **Force Development and Posture.** Military procurements became the most serious indicators of Soviet intentions, a measure of how willing the Soviets were to use force and what methods they might employ if they did. They maintained large numbers of highly capable tactical systems, and they introduced and modernized nuclear weapons, all of which left little doubt that they were capable of waging offensive war in Europe.
- **Major Exercises and Scenarios.** For both the East and the West, large annual field exercises involving hundreds of thousands of service members and thousands of aircraft and vehicles could and did serve both as rehearsals and as political statements. The fictional scenarios involved portions of real war plans, were always set in the present or very near future, and were based on existing forces and capabilities.

During the Soviet era, it seemed safe to assume that the Politburo was in control of the Soviet military and that the latter adhered to the wishes of the political authorities.

Russia has, however, since been through a wrenching period of change. Today, the elements of policy, military forces, and exercises may sometimes be out of step. Therefore, a new deterrent framework requires an additional element: The highest political authorities should formally endorse military doctrines, major exercises, and the scenarios that drive them. The absence of such endorsements or the appearance of disconnects between the various components of the framework may indicate disagreement within the Russian government, lack of clarity in policy formulation, intentional obfuscation (whether for a domestic or foreign audience), or some combination thereof.

| Analytic Framework and Examination of Current Russian Deterrent Policy | |
|--|--|
| Framework Element | Russian Policy and Actions |
| Authoritative statement of claimed interests | Claims privileged status in neighboring countries under the Medvedev Doctrine. |
| Military doctrine and practice | Recognizes that local conflicts can escalate into regional conflicts that might pit Russian forces against NATO or American forces and believes that Russia would not win such a confrontation without resorting to first use of nuclear weapons. However, as of February 2010, current doctrine indicates that Russia will use nuclear weapons only under threat from weapons of mass destruction or if the existence of the Russian state is at stake. |
| Force development and posture | Currently focuses on preparing ground forces for local conflicts rather than on attempting to replicate the most advanced of U.S. capabilities. Russia has been retiring its legacy strategic nuclear programs but continues to rely on its intercontinental ballistic missiles, such that the force structure may become somewhat lopsided in their favor. |
| Major exercises and scenarios | Has revived the use of large military exercises. To the extent that these exercises have been public since 1999, the scenarios have focused on local conflicts escalating to regional crises drawing in highly capable Western forces and, eventually, Russian recourse to nuclear weapons. |
| Endorsement of doctrine, forces, and exercises from political authorities | Has political leaders who have reengaged with military doctrine. Both Vladimir Putin and Dmitry Medvedev have endorsed the military doctrines and exercises mentioned above, and Medvedev endorsed the new doctrine in 2010. While Medvedev has been less forthcoming about meaning and details, he has been more active in support of new arms control agreements. |

Russia's Emerging Deterrent Framework Differs from Past Approaches in Important Ways

While a number of other things have changed since the end of the Cold War, both Russia and the United States still possess large, powerful nuclear arsenals. Regardless of the lack of adversarial intentions, the very existence and sheer numbers of these weapons demand that each nation continue to deter the other from using them. Moreover, Russia's conventional capabilities have declined to the point that it is at a disadvantage relative to its plausible adversaries, such as the United States and NATO. PAF undertook an examination of why and how Russia may be developing a new position with respect to the United States and the extent to which nuclear weapons figure in the emerging framework (see the table).

Russia still intends to protect its own interests, which include those it sees with regard to its neighbors and historical allies. As President Dmitry Medvedev set out in the foreign policy principles he presented in August 2008, the responsibilities the country has taken onto itself include dissuading potential adversaries from expanding into the region or unilaterally intervening in any local conflicts. But, in the face of its perceived conventional inferiority, Russia previously implied its willingness to be the first to use nuclear weapons.

Russia's deterrent framework should be considered in the context of its reassertion of great-power status, its views on its relationship with the United States, and its evolving position on the role of nuclear weapons in its security planning.

More recently, however, the government has backed away from that position. The new military doctrine it adopted in February 2010 explicitly limits the use of nuclear weapons to situations in which an adversary threatens Russia or its allies with nuclear or other weapons of mass destruction or in which a conventionally armed enemy threatens Russia's very existence.

The new doctrine has not changed the interests Russia claims but does raise questions about how it will defend them and under what circumstances. In seeking both to dissuade NATO expansion and to deter military intervention in peripheral conflicts in which it is involved, Russia faces the challenge of communicating its interests and intentions to other states and gaining support for its policies within its own political and military apparatus. While this new framework has inherited forces, programs, and elements of military doctrine from the Soviet Union, they are being shaped, changed, and sometimes discarded to adapt to Russia's new environment and purposes.

Russia's deterrent framework should be considered in the context of its reassertion of great-power status, its views on its relationship with the United States, and its evolving position on the role of nuclear weapons in its security planning. While it does not encompass the whole of Russian policy or strategy, it is a recognizable new element that is noticeably different from the past and appears to still be in flux.

How Should the United States Respond?

Any U.S. response to Russian claims requires making judgments on how Russia is likely to perceive and act on that response. Before February 2010, among the strategic considerations U.S. policymakers and planners needed to assess was the possibility of being drawn into a conflict that could escalate to Russian use of nuclear weapons. Extant NATO and U.S. policy did not seem to fully capture such a possibility. Without further clarification of the 2010 military doctrine—because of the disconnects between it and past exercises and evident policy directions—U.S. and U.S. Air Force decisionmakers cannot be fully confident about the exact circumstances under which Russia would consider using nuclear weapons or what sort of nuclear use it might consider.

Before the new doctrine, it would have been reasonable to argue that the United States and NATO would need to plan for the changed military environment and geography in Europe to avoid having to decide in the moment whether they were prepared to respond with nuclear weapons and what weapons they might use. Such planning would require an awareness of what sorts of actions and operations raise the risk of a Russian nuclear response or action and of the need to minimize that risk. In some cases, this would suggest avoiding certain actions and operations. In others, to prevent misunderstandings and misperceived signals on both sides, it might require more explicit and direct communication with Russia in planning and preoperational stages than might otherwise be deemed necessary.

The new doctrine may mean that there is less reason to worry about possible nuclear exchanges with Russia, except when Russia feels that its own existence, or that of an ally or allies, is at risk. However, the United

States should still seek a better understanding of Russia's interests and what responses it considers adequate short of nuclear use and should seek to improve communication protocols.

Arms Control Remains an Important Consideration in the Evolving Deterrent Framework

It is also useful to consider the implications of Russia's new nuclear doctrine in terms of its evolving force structure. In the past, stability has relied on arms control constructs, such as the Strategic Arms Reduction Talks (START), and on such visible deterrents as strategic bombers. However, these practices will require rethinking in light of developments in Russian intercontinental and submarine-launched ballistic missile forces and prospective reductions in strategic nuclear weapons under the new START agreement. Future arms control negotiations can usefully take these issues into account.

Retaining the Intermediate-Range Nuclear Force Treaty will be important for the United States. Without it, more, and more-threatening, nuclear weapons would become available despite U.S. efforts to prevent their availability. Similarly, existing commitments within START and understandings about the exchange of information on long-range nuclear sea-launched cruise missiles at least put some bounds on their possible numbers and presumable origins of attacks using them. Including these missiles in new arms control agreements would significantly reduce the size of any potential threat from them.

In the meantime, Russian policymakers and analysts continue to emphasize the strategic deterrence mission of their country's nuclear arsenal and to raise concerns that U.S. missile defense programs do or will undermine Russia's capacity to deter a U.S. nuclear strike. This discussion revives Russian fears and claims made during the "Star Wars" era and revisits some of the same proposed responses, such as launch on warning. However, key elements of the command and control and early missile-launch warning systems that would support such a response have not been modernized and have not been given priority.

Implications for the U.S. Air Force

During the Cold War, the Air Force developed a cadre of officers with deep understanding of the Soviets as a military opponent. This expertise was based on extensive experience and study. In any situation in Europe that involves, or risks developing into, conflict with the Russians, there will be a similar need for deep knowledge and for an ability to inform senior political and military leadership on "what comes next" as situations develop. PAF researchers pointed out some of what this awareness of the "nuclear shadow" should entail:

- The U.S. Air Force is the principal component of the American ability to wage war from a distance, in which precision-strike assets destroy ground-based forces. In the event that the Air Force must plan and conduct operations against Russian forces, it should expect to consider at least the possibility of Russian use of nuclear weapons.

Any actions in Europe to support American operations elsewhere have been and will be observed by a Russian military more interested in us than we are in it. It is critical that operational planning take this into account.

- Operations under a nuclear shadow demand many of the same responses as those required for an adversary that has highly accurate in-theater resources. However, the need to deter, prevent, or otherwise avoid the use of nuclear weapons is greater. The Air Force can reduce its in-theater footprint by exploiting its capability for long-range, precision strikes. This, in turn, will reduce the adversary's perception that small attacks can by themselves change the battlefield outcome.
- Any actions in Europe to support American operations elsewhere have been and will be observed by a Russian military more interested in us than we are in it. It is critical that operational planning take this into account and that planners and operators take steps to prevent Russia from mistaking operations and actions as unintended "signals."
- Nuclear systems based in the continental United States are becoming more important for any theater nuclear roles. Similarly, intelligence and surveillance assets based and operated in the continental United States will permit the Air Force to ensure its ability to produce in-theater effects with reduced exposure to in-theater attack.

For More Information

Nuclear Deterrence in Europe: Russian Approaches to a New Environment and Implications for the United States, by James T. Quinlivan and Olga Oliker, MG-1075-AF, <http://www.rand.org/pubs/monographs/MG1075.html>



James Quinlivan

After more than 30 years at RAND, senior operations research analyst James Quinlivan is still a believer in the power of basic math. His research through the years has focused on system engineering and requirement generation. He has, for example, provided insights into the number of forces needed to provide security for stability operations, such as recent U.S. operations in Iraq and Afghanistan. "Although numbers alone do not constitute a security strategy, successful strategies for population security and control have required force ratios of at least 20 security personnel (troops and police combined) per thousand inhabitants," he explains. "This figure is roughly 10 times the ratio required for simple policing of a tranquil population." In Jim's view, getting the numbers right helps people understand the scale of what needs to be done in a given situation and helps them decide whether they want to do it.

Jim's advanced degrees in mathematics and engineering, his experience as an Army field artilleryman in Vietnam, and his long tenure at RAND have given him the opportunity to examine policy problems from multiple angles and in different contexts, as with his study of deterrence. "There is a revitalized interest in deterrence," he notes. "It's time to rethink exactly what the term means and determine whether deterrence continues to protect U.S. interests." Communication is a key ingredient. "There's an element of contract law in deterrence. It's important to get the terms clear even though it's difficult for the adversaries to talk."

Much of Jim's research has focused on the Air Force. Among the studies he has worked on, he managed a long-term effort to model stealth systems. He considers his participation in such studies to be one of his most satisfying RAND experiences. He recalls that "the first major project, co-led by Glenn Buchan and Bart Bennett, was very important in informing the way the B-2 bomber was viewed in the post-Cold-War world, and it prepared PAF for a series of analyses focusing on stealth technology."

Jim has also enjoyed the opportunity to work in other RAND units as a senior manager. He has served as a RAND vice president and director of the RAND Arroyo Center, the Army's Research Division, and he has worked in RAND Health on such projects as estimating future health care needs for the state of Rhode Island. He appreciates the seriousness of his research efforts and the opportunity to affect policymaking. "How people think affects the way things are done," he says. At the same time, he acknowledges that the answer to a policy question is sometimes "I don't know. But you want to get to a response of 'I don't know' through hard work rather than lazy ignorance."

"Policy analysis doesn't always give you the conclusion you expect or the one you personally prefer," he says, explaining that this also applies in his personal life. When he married, he and his wife, Valerie, expected to sell his house, which, at 1,100 square feet, was too small for the two of them. But before they put up a For Sale sign, they crunched the numbers to determine whether it would be more economical to remodel than to sell. They were surprised to discover that remodeling was clearly the best option. Today, Jim and Val still live in the same house on the same foundation, but now there's plenty of space for their library and for Jim's wood-working shop, where he relaxes by making furniture and other specialty items.

Although numbers alone do not constitute a security strategy, . . . getting the numbers right helps people understand the scale of what needs to be done in a given situation and helps them decide whether they want to do it.

Cost Estimation and Cost Analysis in Project AIR FORCE

An Enduring Capability

The RAND Corporation's history with cost estimation and cost analysis began in the 1950s when it established the Cost Analysis Department in PAF and the development of *parametric cost analysis*—the use of such design elements as aircraft weight and speed to predict costs. Subsequent studies applied this approach to radars and aircraft, and PAF researchers developed models for using it in other contexts as well. The study results and methodologies were influential, gaining acceptance not only from the Air Force but also from other research agencies and the Congressional Budget Office. However, with staff attrition and shifting research priorities, this capability gradually waned in the late 1980s and early 1990s.

Then, in 1997, Lt Gen George K. Muellner, who was at the time the military deputy to the Assistant Secretary of the Air Force for Acquisition, delivered good and bad news to PAF's director. The good news was that the Air Force was still using cost-estimating relationships RAND had developed decades earlier. While that attested to their quality and value, the bad news was that changes in materials (such as the introduction of composites), propulsion, and manufacturing processes, as well as the advent of stealth, had made the old relationships inaccurate. Developing new ones would require multidisciplinary research, and the Air Force lacked the necessary range of skills. He therefore provided funding to help PAF build and sustain an independent and credible cost-estimating capability.

PAF Established a Center of Excellence for Cost Estimation

PAF then set out to reinvigorate its cost-estimating capability. The goal was to build and sustain a capability that could serve the Air Force (and, by extension, other DoD elements) over the long term. PAF's Resource Management Program was a natural home for the rebuilding effort. The first step was to attract people with the right mix of academic credentials, skills, and backgrounds and to enlist the assistance of current RAND researchers with the requisite skills. Key new hires were John C. Graser,



The Lockheed Martin facility in Marietta, Georgia, is home to the final assembly line for the F-22 Raptor, the Air Force's premier air-superiority multimission fighter.



The study results and methodologies were influential, gaining acceptance not only from the Air Force but also from other research agencies and the Congressional Budget Office.

a former Air Force officer who had also been the head of the Air Force's Cost Analysis Improvement Group, and Obaid Younossi, who had been doing cost analysis work for the Navy. In both cases, familiarity with relevant databases and knowledge of the aircraft industry were as important as traditional academic disciplines. The new team began by addressing the changes in materials, fabrication, and propulsion:

- **Materials and Fabrication.** The Advanced Materials Study focused on how material mix, manufacturing techniques, and geometric part complexity affected the cost of military airframes. Notably, the resulting report contained overviews of the materials most critical to airframe manufacture and of the relative advantages of both traditional and evolving part fabrication techniques (Younossi et al., 2001). This information would be especially valuable to program managers who did not necessarily have detailed knowledge of these areas. It then discussed how aircraft costs varied with the material mix of the aircraft's structure.

In general, PAF researchers found that, due to the advent of new processes and technologies, composite parts were much less expensive to manufacture than historical cost data indicated. However, composite airframe parts were still more expensive than comparable metal parts, often by 60 to 80 percent.

- **Propulsion.** The Military Jet Engine Study developed a new methodology for estimating engine costs. It expanded and improved on earlier RAND methodologies by focusing exclusively on turbofan engines and by treating each model of engine separately. The latter step enabled the research team to consider the relationship between derivative and first-of-a-kind engines. Results showed that the tem-



Two F-22 Raptors fly over the Pacific Ocean during a theater security mission. In recent years, PAF has conducted a series of studies to help the U.S. Air Force estimate and manage the procurement and sustainment costs of this versatile aircraft.

perature of the rotor inlet, full-scale test hours, and whether the engine was new or a derivative were the most significant influences on development time (Younossi et al., 2003). However, researchers also noted that the degree of error in estimates of development time and cost is high, so the cost-estimating relationships should be used only during the conceptual stage of aircraft development.

PAF Expanded Its Cost-Estimating Capability to Include Acquisition Issues

As PAF restored its cost-estimating capability and published influential studies, researchers and policymakers alike saw other potential applications of its cost expertise. The focus then broadened to include acquisition and centered in particular on the most cost-effective ways to buy things:

- **Efficiency.** The “Cheaper, Faster, Better?” study explored whether applying commercial approaches to buying weapons could lead to lower cost acquisitions in less time. Research results indicated that the use of commercial parts in Air Force aircraft would likely increase regardless of whether a civil-military integration strategy was implemented. A study of avionics components indicated that commercial parts, components, and design processes could reduce cost and schedules for at least some components. The research team further recommended that future programs include greater risk-sharing between contractors and the government. The principal benefits of using this strategy for the acquisition reform pilot programs derived from structuring and managing these programs more as they would be in complex commercial product markets, in which buyers and sellers establish and achieve price and performance targets in a cooperative environment. The real promise of civil-military integration, they concluded, is to help insert the incentives for price discipline and high performance prevalent in the commercial marketplace into military research and development (Lorell et al., 2000).
- **Comparing Acquisition of the Raptor and the Super Hornet.** The Air Force’s F/A-22 Raptor program had experienced significant delays (52 months) and cost overruns (\$7.8 billion), while the Navy’s F/A-18E/F Super Hornet was delivered on budget and without significant delays. The Air Force wanted PAF to identify what contributed to the delays and overruns for the F/A-22 and what aided the cost and schedule stability of the F/A-18.

PAF analysis showed that multiple factors contributed to program outcomes. Concerns about technical expertise and the industrial base led the Air Force to distribute the F/A-22 work equally among three contractors. By contrast, the F-18E/F program used established relationships to minimize technological risk. The F/A-22 relied on concurrent development of new technology, which created greater technical challenges, while the F-18E/F opted for incremental improvements, which reduced the technical risk. Additionally, the

The Air Force and the Navy asked PAF to analyze the history of fixed-wing aircraft production to determine why these costs have risen faster than just about anything else.

programs allocated different budget shares to the management reserve, which is designed to enable the program to deal with problems that crop up in a development program. The F/A-22, which was much more challenging from a technological perspective, allocated 2 percent of its budget to the management reserve, while the F/A-18E/F allotted 10 percent.

Key lessons the research team identified include setting early and realistic cost and schedule estimates, having a stable development team structure, and recognizing that concurrent development for the airframe, avionics, and propulsion can invite significant risk. They also noted that avionics and aircraft weight require careful attention early in the program. The former is a significant cost driver, and the latter can give an early signal of problems.

- **The Spiraling Cost of Fixed-Wing Aircraft.** The Air Force and the Navy asked PAF to analyze the history of fixed-wing aircraft production to determine why these costs have risen faster than just about anything else. PAF researchers determined that the cost escalation had two major drivers. The first of these, accounting for about one-third overall, was economics, including such factors as labor and materials. The second driver, customer demands, accounted for the rest (Arena et al., 2008).

Staff Sergeant Erik Lucas checks components atop a turbofan engine for the C-5 Galaxy heavy-cargo transport, one of the world's largest aircraft. Each engine produces 43,000 pounds of thrust, weighs 7,900 pounds, and is nearly 27 feet long. PAF developed a new methodology for estimating turbofan engine costs and determined the most significant influences on development time.



A Navy F/A-18E/F Super Hornet flies over the aircraft carrier USS *Abraham Lincoln* in preparation for landing on the ship's flight deck. PAF researchers compared acquisition of the Super Hornet with the USAF's F-22 Raptor to identify reasons for delays and cost overruns for the latter aircraft.



Customer demands influencing cost escalation included such things as a desire for greater stealth and lower weight. But knowledgeable industry observers also cited government regulations, such as those designed to protect U.S. industry, as contributors. PAF researchers identified a number of ways the military services and the Department of Defense could curb cost escalation, including more-stable procurement and long-term contracts. These could encourage manufacturers to invest in efficiency improvements. Fewer change orders could also help reduce costs. Using successive upgrades to improve aircraft rather than buying new types of aircraft could also help contain cost escalation. International competition for aircraft might also reduce cost escalation, but Congress would likely not see that strategy as feasible.

- **The F-22A Multiyear Contract Study.** Multiyear contracts may cost less than a series of single-year contracts. Although the Air Force was in the process of awarding three-year contracts to produce 60 F-22As, Congress wanted to assure itself that the government would realize the promised savings. PAF researchers found that a multi-year procurement of three lots of F-22A fighters would save an estimated \$411 million, about 4.5 percent of the total contract value. Moreover, they were able to trace 70 percent of the \$411 million to substantiated savings estimates the contractors identified (Younossi et al., 2007). Examining the issue of multiyear savings using several approaches produced a consistent range of results, indicating that the savings the contractors attributed to multiyear contracts appeared to be reasonable.
- **The F-22 Tooling Study.** By 2010, the F-22A program was winding down, and it became necessary to determine what tooling should be kept. Some would be required to sustain the aircraft, but tooling used

John C. Graser

As a young boy from a Cleveland suburb, John C. Graser became intrigued with flying, in part from watching F-104 Starfighters on the local TV channel's nightly signoff. As a teenager, Jack logged about 20 flying hours as part of a high school aeronautics course. While that alone might have suggested that he was destined for a career in aviation, it was not his original plan. Instead, he graduated from the University of Dayton with a bachelor's degree in accounting and was headed to law school—until the Vietnam War intervened.

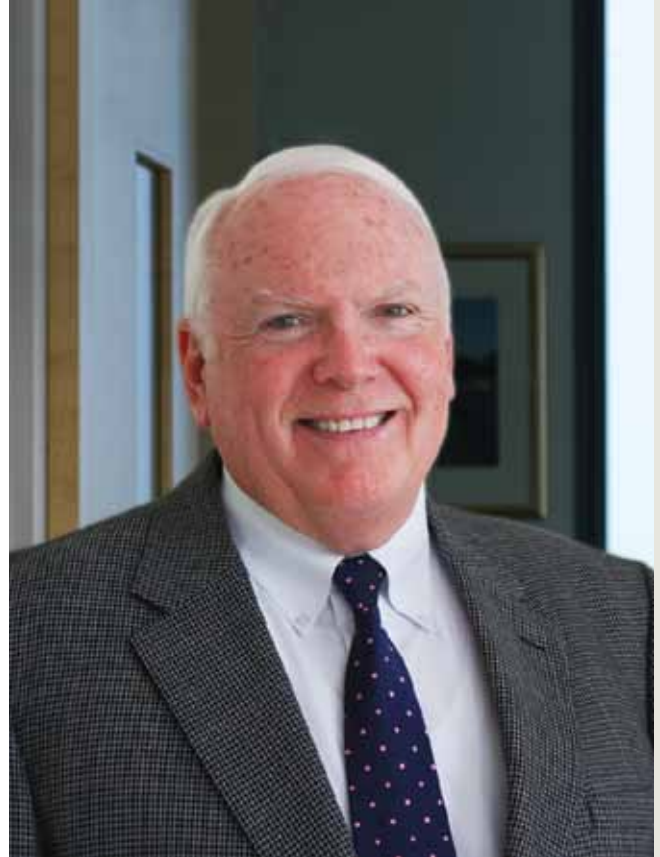
Jack opted to join the Air Force and qualified for Officer Training School. Although he was interested in finance and accounting, the slot the recruiter offered was as a munitions officer, overseeing the loading of bombs on aircraft. Thinking it would be a short-term assignment, Jack accepted. His hitch lasted for 24 years.

After 18 months as a munitions officer, he went to flight training and ended up piloting F-4 Phantom jets, the Air Force's premier fighter at the time. As Jack puts it, "that's what kept me in." He flew F-4s for nearly a decade, including 195 combat missions over Southeast Asia. As Jack describes it, "one of the big lessons of flying in combat is that, when you've been shot at, you know inside yourself that you can always do what you've got to do because it will never be that bad again."

Knowing what he has to do has stood Jack in good stead. After Vietnam, he earned an MBA from the University of Utah. Following an early promotion to major, he joined the Air Force Inspector General's team in Europe and then attended the Armed Forces Staff College in Norfolk, Virginia. Then came a four-year tour at the Pentagon. Jack would later graduate from the National War College at Fort McNair, Washington, D.C., and the program manager's course at Fort Belvoir. He retired as a colonel in 1991, concluding his career with eight years as a comptroller. As a civilian, he went back to the Pentagon, this time as head of the Air Force's Cost Analysis Improvement Group.

Jack joined RAND in 1997 as head of the new PAF center of excellence for cost analysis. Since then, he has led the cost group, where he has been the principal investigator or participated in more than 30 major studies. One of the most memorable was a short-turnaround, high-visibility study on F-22 tooling done to answer congressional concerns. The study's objective was to make recommendations about the tooling of the F/A-22 Raptor, for which production was winding down. But the results were politically sensitive because some members of Congress wanted the production line closed permanently, while others wanted to retain the tooling so that the line could reopen if desired. Jack's approach to this contentious issue was straightforward: "Call it like we see it." The study's conclusion was also straightforward: For about nine cents on the dollar, all the tooling not needed to sustain the Raptor could be stored.

Jack's return to the leadership of the cost group has given him the opportunity to carry out a number of studies important to the Air Force, the Department of Defense, and the nation. But it has also made it difficult to pursue some of his other passions. He has been a boater for 30 years (he has a merchant marine captain's license) and likes tinkering with cars. "If something has a motor and moves, whether it's an aircraft, a boat, or a car, I like it."



One of the big lessons of flying in combat is that, when you've been shot at, you know inside yourself that you can always do what you've got to do because it will never be that bad again.

only in production could be disposed of or stored. Some members of Congress wanted to retain the production tools as a hedge against restarting the line, possibly producing aircraft for foreign military sales. Others wanted to dispose of the tools, in part to preclude any possibility of new production. In a quick-turnaround effort completed in about 90 days, PAF researchers, drawing in part on earlier F-22A studies done for the Air Force, examined two scenarios: (1) shut down the line and keep only tools needed for sustainment and (2) shut down the line and retain the tools needed for production. The analysis showed that the cost of retaining the production tooling was modest, amounting to a one-time cost of \$17 million, or about 9 percent of the original acquisition cost of the tools, and annual recurring costs of about \$150,000. Having the tooling available provides a reasonable hedge in the event of a service-life extension program or major accident repair requirements.

Conclusion

Over the 15 years that followed, the investments the Air Force and RAND made produced over 20 high-quality studies and resulted in a cost-estimating capability that has provided the Air Force with a flexible, responsive, and credible tool that can deal with a wide range of cost issues and respond quickly to requests. That capability has gone far beyond the excellent but narrow skill set that produced the parametric cost-estimating relationships of the 1950s. PAF can still conduct such studies, but it can also explore higher-level policy questions. The benefit not only accrues to the Air Force and PAF but also extends to the other federally funded research and development centers housed at RAND. Both the Arroyo Center and the National Defense Research Institute have drawn on the PAF-generated capability to explore cost-estimating and cost-related problems. The diverse set of skills and knowledge that have been amassed provide the Air Force and, indeed, the nation with an invaluable and unmatched resource.

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On the Run

Denying al-Qa'ida Safe Haven in Northwest Pakistan

U.S. strategy for defeating al-Qa'ida emphasizes denying its leaders and fighters safe haven, especially in the border region between Pakistan and Afghanistan. While not always “safe,” these havens have sheltered members of al-Qa'ida as they planned and coordinated activities against NATO-led forces in Afghanistan and sponsored attacks against the United States and Europe.

Havens are by nature difficult to eradicate. They often exist in inaccessible terrain and contain entrenched adversaries supported by sympathetic populations. PAF examined the threat from militant havens in northwest Pakistan. PAF's analysis focused on two areas in this region (see the figure on page 48), the Federally Administered Tribal Areas and the province of Khyber Pakhtunkhwa. In these areas, havens are used by both al-Qa'ida and associated movements (AQAM). The latter include the Afghan Taliban; the Pakistani Taliban, an auxiliary of the Afghan Taliban; and the Haqqani Network, an Afghan insurgent group. The research team analyzed the nature of the havens AQAM uses and efforts to dismantle them, identified lessons learned from past campaigns against havens in other countries, and made recommendations for the U.S. national security community, including specific roles for the Air Force.

AQAM Depends Heavily on Access to Havens

PAF's analysis of strategic documents and statements from al-Qa'ida leaders indicates that they believe havens are essential to sustaining their jihadist campaigns globally and to their support of local insurgencies. Havens provide AQAM with significant benefits:

- **Command and control bases** enable AQAM leaders to strategize and plan key operations with relative ease. They also allow them to confer with and discipline field commanders, shelter the families of AQAM members, and reach out to supporters and recruits.



Pakistani Taliban members hold their weapons as they gather before leaving the Buner district in northwestern Pakistan's province of Khyber Pakhtunkhwa on April 24, 2009.

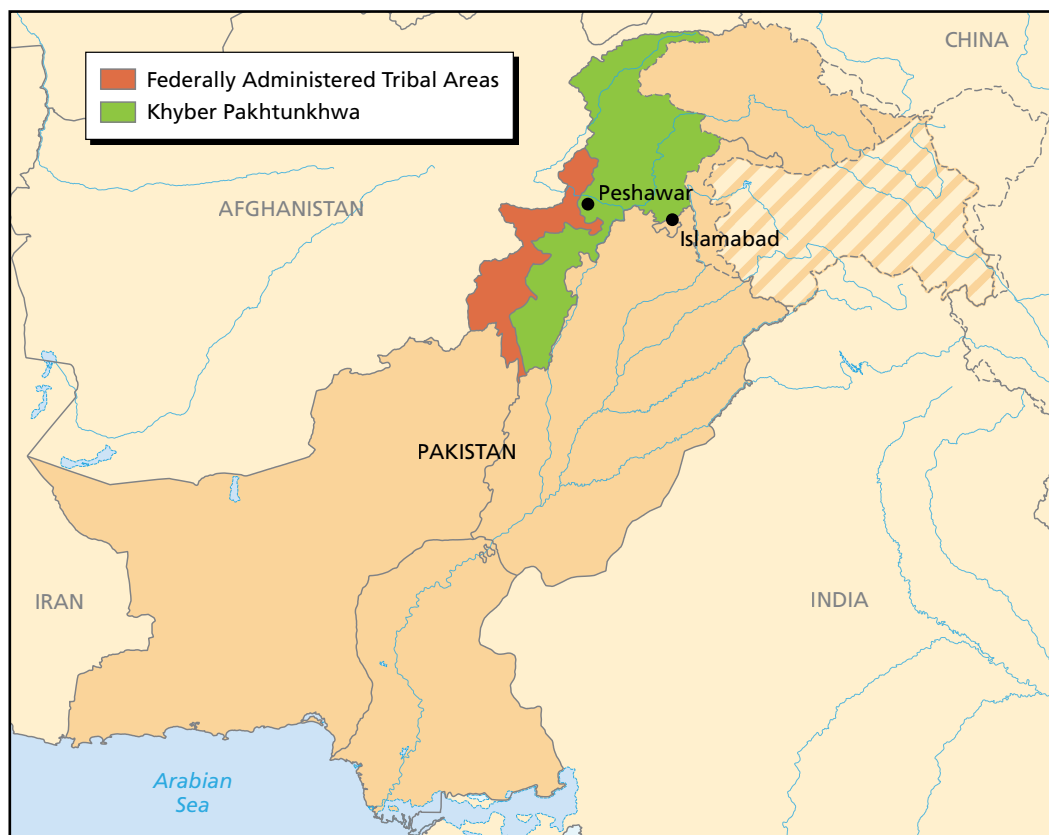


Differing objectives sometimes fray relationships within AQAM, but its components share a common interest in maintaining havens in the area, and their alliance endures.

- **Transit hubs** facilitate the movement of people, money, and weapons into and out of areas of conflict. They also often serve as staging areas along logistical corridors and as bazaars for weapons.
- **Operating bases** provide immediate access to areas of conflict and desired targets.
- **Training camps** enable AQAM leaders, facilitators, and trainers to indoctrinate new recruits. One Taliban commander observed that 80 percent of the fighters in his district (280 fighters) had been trained in Pakistan. Training camps have also played an essential role in helping AQAM maintain its global reach.

AQAM factions use havens in the border area to pursue different, sometimes conflicting goals. Al-Qa'ida, for example, uses them to wage global jihad and to support local insurgencies, such as the Pakistani Taliban's efforts to overthrow the government of Pakistan and impose an Islamic state. Its support for the Pakistani Taliban helps al-Qa'ida maintain access to havens but puts it at risk of reprisals from the government of Pakistan.

Al-Qa'ida's support for the Pakistani Taliban also strains its lengthy relationship with the Afghan Taliban, which primarily uses havens to facilitate its operations in Afghanistan. To reduce any threat to its fight in Afghanistan, the Afghan Taliban has kept a low operational profile in the border areas and avoided attacks against the Pakistani state. Members of the Haqqani Network conduct attacks within Afghanistan but



This array of weapons and ammunition was recovered during Pakistani military operations against Taliban militants in October 2009 in South Waziristan, a region that also provides safe haven for al-Qa'ida fighters. The Pakistani military had been waging an offensive against Taliban fighters believed to be behind most suicide bombings in the country.



are also deeply involved in smuggling and other criminal activities in the border area. These differing objectives sometimes fray relationships within AQAM, but its components share a common interest in maintaining havens in the area, and their alliance endures.

AQAM maintains access to havens through interactions among its member organizations and through an equally complex system of ties with local powerbrokers, such as Pakistani state officials and tribal leaders. For example, Pakistani Inter-Services Intelligence has a long history with the Haqqani Network and the Afghan Taliban and is said to use these factions as proxies to exert influence in Afghanistan. Ties to local powerbrokers are unpredictable and prone to fracture. The Pakistani Taliban has assassinated tribal leaders, and elements of Pakistan's government have attempted to control AQAM by playing one faction against another and by turning tribal leaders against AQAM.

Although tensions rise and fall among the various actors, AQAM's havens have proven resilient. Given the complex human networks; the physically challenging, mountainous terrain of northwest Pakistan; and the inherent difficulty of evicting insurgents from any haven, the PAF analysis concludes that havens in the region are unlikely to collapse without substantial external pressure.

Current Pakistani Efforts Are Likely to Fall Short of Eliminating Havens

The PAF team assessed four recent Pakistani military operations in the region. Its assessment shows that Pakistan has made significant efforts to combat the Pakistani Taliban in the region since 2008. The military has increased the number of troops deployed in the northwest from 100,000

One of the key findings from the case studies is that terrorists and insurgents tend to abuse the hospitality of host nations.

to 150,000 and has improved its tactical performance in recent operations. Nevertheless, challenges are evident.

Pakistan continues to view India as its primary threat, largely overriding its concerns about nonstate adversaries—with the exception of the Pakistani Taliban—and limiting its willingness to devote sufficient resources to combating AQAM. The number of troops in the region still falls 70,000 short of the standard force ratio of 20 counterinsurgency troops for every 1,000 residents. Because it is overextended, Pakistan uses local security forces, such as tribal militias, to combat AQAM, but these forces are ill equipped and ill trained to go up against AQAM fighters. On the civilian side, even after receiving funding from the United States, the Pakistani Federal Investigative Agency has yet to become involved in terrorism arrest, prosecution, and trials. In addition, Pakistan's court system appears to be a revolving door for captured AQAM fighters. Finally, sensitivities over its sovereignty and a high level of anti-American sentiment among the Pakistani public make Pakistan reluctant to accept a greater U.S. presence in the region.

Lessons Learned from Past Campaigns

PAF researchers examined the successes and missteps made in previous campaigns against havens in Vietnam (1962–1973), Jordan and Lebanon (1968–1982), Sudan (1991–1996), and Iraq (2003–2008). One of the key findings from the case studies is that terrorists and insurgents tend to abuse the hospitality of host nations. For example, the Palestine Liberation Organization (PLO), which used havens in Jordan to launch attacks against Israel, threatened to undermine the legitimacy of King Hussein's regime by offering social and medical services, establishing diplomatic



Pakistani troops walk through the damaged market in Sararogha, a town in the troubled Pakistan tribal region of South Waziristan along the Afghan border.

| Past Campaigns Have Used a Variety of Instruments to Deny Access to Safe Havens | | | | | |
|---|---------|--------|---------|-------|------|
| Instrument | Vietnam | Jordan | Lebanon | Sudan | Iraq |
| Pressuring host nations diplomatically to oust militants | X | | | X | X |
| Negotiating agreements to limit use of havens | X | X | X | X | |
| Targeting militant leaders to make them feel less safe | | X | X | | X |
| Partnering with local militias to minimize access to territory | X | X | X | | X |
| Expanding social services to fill vacuums departing militants leave | | X | X | | |
| Attacking transit hubs, supply lines, and operating bases | X | X | X | | X |
| Building a barrier (e.g., a security fence) to prohibit infiltration | | X | X | | X |
| Attacking a host nation as a punitive or coercive measure | X | X | X | X | |
| Invading a host nation to occupy havens and create buffer zones | X | | X | | |

and political headquarters, and operating training bases and transit hubs. In Sudan, al-Qa'ida members pressured local populations to adopt their rigid ideology and practices.

In both cases, the abuses persuaded host nations to revoke access to havens in their territories. Diplomatic and economic pressure from external actors also played a role in their decisions, but the case studies show that the tipping point of most successful campaigns occurred when relations between host nations and militants went sour. When Sudan reached this tipping point, it easily expelled bin Laden and his followers, who had relied heavily on that government's support. King Hussein was also able to evict PLO fighters from Jordan, although he had to use his military in combination with tribal militias to do so. He also used aid from other Gulf states to fill the social service vacuums the PLO left. However, some states are not capable of evicting militant fighters on their own, as was the case in Lebanon, where PLO fighters fled after being evicted from Jordan. These findings underscore the importance of working with local partners and improving their capabilities.

If host nations are unwilling or unable to deny havens to militants, attacking transit hubs has generally been more effective than other policy instruments. The table lists the instruments used in the campaigns PAF examined. Although generally more effective than other options, attacks against transit hubs nevertheless had limited effect in past campaigns. For example, in Vietnam, U.S. standoff technologies caused some frustration for Communist forces and destroyed a significant number of trucks but were not enough to eliminate access to havens. Similarly, during Operation Iraqi Freedom, surgical strikes by U.S.- and UK-led

Given the resilience of AQAM's havens and Pakistan's limited objectives for dismantling them, PAF analysts concluded that the U.S. government should expect the havens along the Afghanistan-Pakistan border to continue to be problematic over the long term.

coalition forces against transit hubs supported by Iran were not successful until these efforts were expanded to include attacks against a significant number of Shi'a militia leaders and were coupled with diplomatic pressure. These findings led the PAF analysts to advise that attacks against transit hubs be viewed as short-term solutions.

Recommendations and Implications for the Air Force

Given the resilience of AQAM's havens and Pakistan's limited objectives for dismantling them, PAF analysts concluded that the U.S. government should expect the havens along the Afghanistan-Pakistan border to continue to be problematic over the long term. Since no single policy instrument examined in PAF's case studies has been successful over time and in different environments, they recommend that U.S. strategy adopt a "defense-in-depth" approach: using multiple policy instruments, such as those highlighted in the table on page 51, along with military assistance and efforts to build the capacity of host nations.

Although many aspects of this approach fall outside the purview of the U.S. Air Force, there are still significant implications for Air Force involvement. Because AQAM is likely to retain access to havens in the border region well into the future, there will be ongoing demand for ISR capabilities in the region. The U.S. Air Force should also expand engagements with the Pakistan Air Force to bring existing and newly acquired capabilities, such as Block 52 F-16s, into the fight. Working with Pakistan Air Force planners for airlift and ISR, as well as with the Pakistan Air Force line units that perform these missions, could also help increase their contribution to the fight. For instance, the U.S. Air Force could help the Pakistan Air Force examine concepts for increasing the contribution of its C-130s in resupplying Pakistan Army units involved in counterinsurgency operations in northwest Pakistan. Improvements in this area could reduce Pakistani casualties from improvised explosive devices and ambushes on convoys and reduce demands on the Pakistan Army's limited rotary-wing aviation capacity. Using Pakistan airlift to support civil action activities—such as setting up temporary field clinics to provide basic medical treatment to the local population—could also help enable Pakistani military "hold and build" efforts in key areas.



Kim Cragin

Kim Cragin has conducted fieldwork on terrorist-related issues in conflict zones around the world. In addition to Pakistan (where she led the PAF team that analyzed al-Qa'ida's safe havens) and countries in the Middle East, her research has taken her to Colombia, Djibouti, northwest China, and a half dozen countries in southeast Asia. "I prefer not to write about a place without having been there," she says. "You learn so much when you roll up your sleeves and interact directly with local officials, community leaders, and even spokesmen for militant groups."

Her emphasis on fieldwork is partly due to academic training, but it also has roots in a remarkable confluence of experiences, events, and people. The daughter of an international business consultant, Kim grew up in China. While still in high school, she found herself assisting Americans trying to leave China after hundreds of protesters were killed during the Tiananmen Square protests. "The American embassy asked my father to help coordinate the evacuation effort, but he also had a business to run, so he put me in charge of taking calls. I'd tell panicked U.S. citizens, 'Don't worry, we'll get you out. Just give me your information, and I'll have somebody from the embassy contact you.' I can't imagine what they thought, having a 15-year-old facilitator, but it all seemed perfectly reasonable at the time."

Kim found herself near another hot spot during her undergraduate years at Oklahoma Baptist University, where three generations of women in her family had studied before her. "I was in college at the time of the Oklahoma City bombing," Kim recalls. "It had a big impact on a lot of Americans, particularly in Oklahoma, and it was one of the reasons I became interested in studying terrorism." The following year, while studying in Israel, Kim witnessed Hamas' first systematic campaign of suicide bombings. She went on to write a dissertation on the Palestinian resistance, earning a PhD in history at Cambridge University. She also has a master's degree in public policy from Duke University.

Kim joined RAND one year before the terrorist attacks on September 11, 2001. "After 9/11, I became absorbed in efforts to help the government respond to the attacks. I had planned to stay at RAND for two years, but the policymaking dimension of research at RAND turned out to be a good fit for me." In 2007, RAND awarded her a Silver Medal for her analysis of the terrorism threat to the United States; the award highlighted her dedication to field-based studies, noting that she had put herself in harm's way. In 2011, she received a second Silver Medal, for leading work that changed the tactics employed against terrorist groups in Pakistan and elsewhere.

As Kim discusses her work and family, it is clear that the importance of military service has also shaped her professional life. Both of her grandfathers served in the Army Air Corps during World War II, one escorting bombers over Germany and the other a bombardier on fire-bombing missions over Japan. Both rejoined the Air Force during the Korean War. Kim herself served briefly in a war zone in 2008 when she was asked to join General David H. Petraeus' staff in Iraq. When asked about the hazards involved, she acknowledged that it hadn't been easy. "We were being hit by indirect fire hourly," she says, "But it was important to me to say yes when I was asked to help the warfighters."

I prefer not to write about a place without having been there. You learn so much when you roll up your sleeves and interact directly with local officials, community leaders, and even spokesmen for militant groups.

Project AIR FORCE Research Excellence Awards

In 2008, Project AIR FORCE (PAF) instituted an award to honor researchers who, year after year, have achieved the highest degree of excellence in their work. Winners receive support for professional development and a plaque recognizing their outstanding contributions. The selection committee includes the unit director, Andrew Hoehn; the then–associate director, Carl Rhodes; and the director of staff development, Michael Kennedy. PAF congratulates the 2011 Research Excellence Award winners, Robert Guffey, Lance Menthe, and Jennifer D. P. Moroney, on their record of outstanding accomplishments.

Robert Guffey



Robert Guffey is recognized for his work on long-range strike in PAF and the National Defense Research Institute. He has consistently contributed high-quality support developing and improving communications products in PAF's Force Modernization and Employment Program. The highly technical research this program produces must be intelligible to both nonexpert policymakers and subject-matter experts. Since 2006, Robert has worked closely with research teams to help their briefings and reports achieve this balance.

Robert's role on the long-range strike effort went beyond what is typically expected of a communications analyst. He was integrated into the project team at the very beginning because of the need to communicate this complex technical work effectively to the highest levels of DoD. Robert became familiar with the material, identified and shaped key policy messages, helped structure briefings and documents from the outset, managed the writing process, and assembled coherent final products.

As a former English teacher with no background in military subjects before coming to RAND, Robert also played the role of "intelligent nonexpert," anticipating how high-level policymaking audiences would receive the work.

Robert holds a BA from the University of Southern California and an MA and a PhD from New York University, all in English literature.

Lance Menthe



Lance Menthe is honored for his contributions to the study of Air Force intelligence collection and utilization. He created a model designed to help Air Force planners answer the all-important programming question: How much capability is enough? Despite the importance of rapid and sophisticated intelligence-gathering in current operations, and despite the explosion of such new technologies as remotely piloted aircraft (RPAs) and motion imagery sensors, no previous model had adequately analyzed the cost- and operational effectiveness of different force structure options. To help fill this gap, Lance built the Systems and CONOPS Operational Effectiveness Model, a physics-based simulation that analyzes thousands of platform-sensor combinations against a host of parameters, including weather, terrain, target characteristics, and concepts of operation. The model can also evolve to meet the requirements of different Air Force sponsors and can be adapted to examine specific sensors, environments, aircraft, satellite systems, etc.

His work has placed Lance at the center of innovation in ISR modeling, inspired fellow researchers, and generated a large stream of research that has kept pace with the Air Force's evolving ISR challenges.

Lance earned a BA in physics from the University of California, Berkeley, and an MS and a PhD in physics from the University of California, Los Angeles.

Jennifer D. P. Moroney



Jennifer Moroney is honored for her substantial body of highly regarded work on security cooperation over the last several years. She is well respected in the external community and has many contacts in the DoD community. She often runs large and complex projects and is a mentor to junior staff. Her efforts have played a major role in establishing RAND's expertise in security cooperation and building partner capacity. Indeed, demand for her work is not limited to the Air Force but includes the Army, OSD, combatant commands, Defense Threat Reduction Agency (DTRA), and other interagency actors. As the topic of security cooperation has increased in importance for DoD policymakers, Jennifer has worked diligently to ensure that RAND's work in this area is coordinated across units and leveraged to the fullest.

Jennifer has been RAND's primary point person on the topic of security cooperation for more than five years. She is the lead author of a number of published monographs and is frequently asked to brief senior Air Force, Army, OSD, and DTRA leadership on the subject.

Jennifer graduated from Frostburg State University with a BA in political science, from the University of Limerick with an MA in European studies, and from the University of Kent/Canterbury with a PhD in international relations.

Recent Publications

Strategy and Doctrine

Adding Value to Air Force Management Through Building Partnerships Assessment, by Jefferson P. Marquis, Joe Hogler, Jennifer D. P. Moroney, Michael J. Neumann, Christopher Paul, John E. Peters, Gregory F. Treverton, and Anny Wong, TR-907-AF
http://www.rand.org/pubs/technical_reports/TR907.html

Air Operations in Israel's War Against Hezbollah: Learning from Lebanon and Getting It Right in Gaza, by Benjamin S. Lambeth, MG-835-AF
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